Going Against the Grain: The De-maturity of the European Textile Industry

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Abstract

This thesis aims to challenge the conventional assumption about the irreversibility of the decline of the textile industry in developed countries. It is argued that the decline can be reversed if mature textile firms can break away from their traditional routines and practices and radically and continuously change their technologies, markets and organisational structure to adapt to the rapidly changing business environment.

Using the European textile industry as a case study, this thesis shows that a number of European countries, including Germany and The Netherlands, have managed to bypass the maturity-trap -a phenomenon commonly found in large mature firms because of an inability to adapt to changing external conditions- through industrial reconfiguration from the 1960s onwards. The majority of the industry, however, has been in relative decline over the past decade as the market has become much more competitive and consequently made their old strategies obsolete. Under such circumstances, there is an urgent need to turn the industry around.

Learning from the failure of the Courtaulds (UK) and the success of Ten Cate (NL) and Freudenberg (DE), the thesis illustrates how the maturity-trap can take hold and how the process of de-maturity can be initiated at the firm level. The case study of Marzotto highlights how the danger of the maturity-trap is now no longer just a British phenomenon. This once highly successful firm is now in great danger of falling into the maturity-trap. The issue at stake is the long-term survival of the European textile industry and how rapidly its long-term competitiveness can be restored.

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Fianti Noor

Short Biography

Fianti's initial interest in technology management and innovation studies began when she worked for the Technology Commercialisation Division of the Intellectual Property Management Office of Institut Teknologi Bandung (Indonesia, 2000-2003). During her assignment, she contributed to the commercialization of three technologies and coordinated a number of events to promote new technologies arising from research at the university. She helped the university to set up a business incubator in 2003. During the same period she co-found a consulting firm which operated in the strategic management field. She led two consulting projects for the Ministry of Research and Technology.

To improve her knowledge in the field, Fianti took an MBA with specialisation in Technology Management at Queen Mary, University of London. She received the British Chevening Award from the Foreign and Commonwealth Office (UK). Fianti was offered to start her PhD thesis in 2005. In 2009, she started to work for the Business Development Division of Nanoforce Technology, Ltd.

Table of Contents

List of Tables

List of Figures

1

Introduction

The textile industry is one of the oldest manufacturing industries which grew rapidly during the Industrial Revolution in Britain. The long history of the industry and its transformation is arguably an invaluable case-study when analysing the process of economic change. Indeed, the industry has been characterised by changing industrial leadership since the 20th century which has swung increasingly in the favour of countries from the East. Following the supremacy of the Lancashire cotton industry in the 19th century until the first decade of the 20th century during which it dominated 80 per cent the global cotton product market, Japan emerged as the new dominant power in the global textile trade between the 1930s-1970s. The 1980s witnessed the transition period where a number of developing countries, notably Hong Kong, South Korea, Taiwan and China, emerged as the major competitors in export markets. Since the 1990s China has proceeded to gain an increasing share in the textile and clothing export markets which was reinforced further by its accession to the World Trade Organisation (WTO) in 2001 and the cessation of the protectionist trade regime at the end of 2004.

The changing industrial leadership appears to confirm the conventional assumption which contends that that the developed economies should cede mature, traditional manufacturing industries to the developing world (see for example Froebel, *et al.*, 1980). The assumption is based on the supposition that the developed countries cannot be competitive in the industries which are labour intensive, low technology and cost driven. On the contrary, the developing countries with their low-wage labour can supply cost-sensitive markets with significantly lower priced products. Consequently, the developed economies have assumed they should transfer their traditional manufacturing industries to the developing countries and establish service industries. In other words, the decline of the British and the European textile industry in general is 'irreversible'.

The *central purpose* of this thesis is to challenge this conventional view. In contrast to the traditional view, Abernathy *et al.* (1983) argued that maturity could be arrested and, even more, reversed so that the developed countries could regain their competitive advantage in mature industries. The concept, known as de-maturity, suggests that firms need to radically change the characteristics and performance of the existing products or to create new markets that lead to the formation of new sectors or industries (Abernathy, *et al.*, 1983). The concept suggests that the process of maturity is not inevitable provided that firms can move up the value chain, and continuously produce higher value added products in demand (often through product and technology diversification) and manufacture them efficiently and effectively.

Indeed, following the collapse of the British textile industry, the German and the Italian textile industries emerged as the new leaders in the textile market in the 1970s. Unlike the British textile firms that focused on the low value-added market segment, the German and Italian firms offered high value-added products for technical applications and the high-fashion market respectively. They constantly introduce new trends in their respective markets with Germany focuses on the development of new technologies and new materials while Italy on the creation of new aesthetic designs. The Dutch textile industry, although its size is much smaller than the two leaders, its productivity is higher than those countries. This shows that these countries have managed to turn the industry around and initiate the process of de-maturity.

Surprisingly, the concept of de-maturity has *rarely been discussed* in the innovation literature. In fact, innovation studies in the low-medium technology sectors, in which the majority of mature industries are classified, have been under valued or neglected (Robertson, *et al.*, 2009, von Tunzelmann and Acha, 2006). The importance of the study about industrial de-maturity is of major importance to both the industrialised and less-industrialised economies. The reason being mature industries are still the major contributors to manufacturing output and employment (Hirsch-Kreinsen, *et al.*, 2006). The lack of analyses has made factors central to the decline of mature industries in the developed countries are largely unknown. This may answer the longevity of the conventional assumption about mature industries.

According to Abernathy *et al.* (1983), one fundamental factor which causes the decline of mature industries in the developed countries is the phenomenon of the 'maturity-trap'. They suggest that that large firms operating in mature industries often cannot foresee the potential impact of external changes to their position of leadership. Even if they recognise the change, they are incapable of making a rapid and adequate response due to deeply entrenched values and practices that have been built over a long period of time and have brought success to the firms. Whilst observed 30 years ago, the phenomenon is very much alive today. The most recent instance is the collapse of General Motors (GM) and Chrysler during the global economic recession in 2009. The firms with a dominant position in the market became 'powerless' when markets they operated in changed very quickly. Being rigid and unable to change sufficiently and rapidly has cost the American government \$70 billion (€49 billion) without any guarantee that the firms will thrive in the long run. Other firms in different industries including RCA and Philips (colour televisions) and Motorola (mobile phones) have also fallen victim to the trap. These examples confirm that the maturity-trap has become a chronic 'disease' affecting various industries that has never been properly addressed.

If such large and dominant firms are vulnerable to the same trap, it is therefore very likely that the European textile firms are also vulnerable to such a trap. The central issue here is whether there is any 'solution' to bypass the maturity-trap. The obvious pre-requisite is innovation. Encouragingly, it has been shown that the textile industry is in fact far more dynamic and innovative than has widely been assumed. The industry constantly upgrades and adopts new high technologies to provide improved or new products for their customers (von Tunzelmann and Acha, 2006, Sandven, *et al.*, 2005). However, the process and the extent of firms' innovativeness and dynamism required to initiate de-maturity needs to be investigated as neither von Tunzelman and Acha nor Sandven discuss the issue. Sull (2000) finds that firms do respond to a changing competitive environment through the adoption of new technologies and product development. However, the responses are often simply not sufficient or too late. Innovation to reduce costs alone is often insufficient to escape from the maturity-trap. On the other hand, the adoption of advanced technologies without the ability to successfully exploit them will not generate competitive advantage for the firms. Sull argues this is the underlying factor that caused the decline of Firestone, the incumbent in the tire market, in the face of new competition from Michelin that introduced radial tires to the market. This is also one of the factors that precipitated the demise of Courtaulds, the largest textile group in Britain. At the industry level, the Lancashire cotton industry, once the world's largest cotton industry, was the first victim of the maturity-trap.

1.1 The Objective of the Thesis

It was discussed earlier that a number of the EU countries, notably Germany, Italy and the Netherlands, have succeeded in transforming their traditional textile making capabilities into the production of high value added textiles. The process of transformation required a long process of transition in knowledge, technology and market and the creation of new competencies. The process was driven by the adoption of advanced textile and material processing technologies and the creation of new markets.

The objective of the thesis is to examine the textile industry, particularly in the EU, and show why it does not fall into the category of a mature industry. In fact, the industry is highly dynamic and flexible in parallel with the high-technology industries. It is true that the traditional market of this industry has reached maturity; however, maturity is not necessarily an irreversible process as it has been widely believed. This conventional belief has led to the assumption that industrialised countries should let their textile industries 'migrate' to developing countries. It is argued that this is not always the case and the process of maturity can be reversed.

To explain the argument, it will be shown that traditional textile firms have to break away from or bypass the maturity-trap to initiate the process of transformation and become R&D-led textile firms. De-maturity can only be achieved if firms possess certain levels of innovative capabilities to create new competencies away from their current competencies and to adapt to a changing business environment. Such a strategic redirection not only requires technological capabilities but also organisational capabilities (Doz and Prahalad, 1988). Those which cannot or are not willing to initiate the process of de-maturity are very likely to fall into the maturity-trap. This will increase the likelihood of bankruptcy or being acquired by other firms.

The second objective of the study is to examine the efficacy of the EU initiatives for the rejuvenation of the textile industry. The government should play an important role to accelerate the process of building up the innovative capability. It is highly crucial as the long-term competitiveness of the EU textile industry depends on the capability of textile firms to initiate the process of de-maturity and, furthermore, undertake continuous change. The introduction of the 'European Technology Platform for the Future of Textile and Clothing – A Vision of 2020' in 2004 to promote the scenarios and strategic development agenda for the long-term competitiveness of the industry shows the government's serious intention to change the industry. It is argued here that the initiative whilst crucial is not sufficient to rejuvenate the industry. The reason being the majority of the EU textile firms lack the necessary capabilities to allow them to initiate strategic redirection. This is discussed in Chapter 3, 5, 6 and 7 that technological innovation should be complemented with organisational capabilities that include entrepreneurial management and good leadership. These are in fact the major factors that contribute to the decline of the Lancashire textile industry as argued by Lazonick (1981, 1983).

1.2 The Importance of the Thesis

The past decade has been a challenging period for the EU textile industry. The industry has suffered from steady decline where textile output fell by 28 per cent and clothing output declined by 30 per cent between 2000-2008. Employment in the EU shrank by 443 000 (20 per cent) which forced 19 568 (18 per cent) firms out of business between 2000-2004. Turnover dropped by 12.5 per cent during the same period. At the national level, the performance appears to be less encouraging. In 2006 Britain employed 155 000 people or only 22 per cent of its employment level in 1963, while turnover declined sharply by around 33 per cent between 2004-2006. In Germany employment declined by 68 000 (36 per cent), while turnover dropped by 21 percent during the same period. Italy employment fell by 30 000 (five percent), while production and turnover levelled off during the period although the longer term trend showed a steady decline. More alarmingly, the value of imports showed an upward trend. Between 1990-2000, 80 000 textile/clothing firms disappeared in Italy, and an additional 13 594 firms went out of business between

2001-2006. To make matters worse, the global economic recession in 2008 hit the Italian textile industry very badly. In October 2008, Versace, one of Italy's most prominent luxury fashion brands announced it was to cut 30 per cent of its workforce and production due to plunging demand. Gianfranco Ferre, another big name in the market, filed for bankruptcy in February 2008. The industry needed €35.16 million from the EU's Globalisation Fund (EGF) in December 2008 to support 6000 Italian textile workers who were made redundant from a combination of an increase in outward processing and an increase in imports of cheap textiles from low-wage economies.

It suggests that the industry has been snared in the maturity trap of once competitive products developed between the 1980s-1990s, shorter product lifecycle, and rapid changes in market and technology. Obviously, the protectionist measures under the Multi Fibre Agreement which was in operation between 1974-2004 did not halt the decline. The industry needs to embark on radical change just like it did in the 1960s-1980s in order to regain its competitive advantage. The radical change should affect every aspect of the business organisation including technology and production systems, products and markets, and organisational structure and routines. Such radical change is critical as being stuck in the maturity-trap and unable to change sufficiently in the current competitive environment has more devastating impact than it did in the 19th century given the intensity of competition, complexity of technology and market demand. The industry needs to heed the lessons of the past and examine the efforts made by the firms in the 1960s-1980s to transform the textile industry.

The lesson from the decline of the British textile industry, which will be discussed in Chapter 3, is relevant to the current environment. The EU should avoid the mistakes made by its predecessors. Rather than protecting the industry, the government should encourage firms to be more dynamic and innovative in their response to a changing competitive environment. Firms should be able to read the likely changes in the future, understand the impact of such changes on their leadership and to respond rapidly and in an appropriate manner. The success of the German textile industry in pioneering the development of technical and performance textiles in the 1970s could be used as an initial point of reference to initiate the process of de-maturity.

Industrial de-maturity can only be achieved if the majority of firms in the industry can rejuvenate their organisations. Therefore, the diffusion of technology is critical to the successful initiation of the de-maturity process. The efficacy of the current EU initiatives that emphasise on R&D, the creation of networks and collaboration between them requires further scrutiny. The development of networks, whilst deemed necessary to improve flexibility in the competitive environment characterised by rapid changes in technology and demand (Chesbrough, 2006), will in all probability face a number challenges in their implementation. Harsh competition may impede stakeholders to work together to build up networks of alliances for the development and commercialisation of new technologies. This is in fact one of the major problems identified by which impeded the formation of an integrated structure in the Lancashire cotton industry and caused the industry to become technologically backward (Lazonick, 1983). Moreover, the complexity in managing the collaboration of diverse teams due to different interests of individual firm, different structural and cultural issues as well as the lack of managerial skills to manage broad scope of knowledge also needs to be approached properly.

Furthermore, the initiatives may not be sufficient to address the underlying deficiencies, that is, the lack of entrepreneurship to drive the commercialisation of technologies and good management. Therefore, efforts should be directed to overcome such deficiencies to improve the innovative capabilities of the firms to the extent at which they allow a *continuous* creation, adoption, and commercialisation of new technologies. The capabilities should enable them to significantly improve current products as well as create new products for existing and new markets better and faster than their competitors. Continuity can only be achieved if innovation is built as an *integral part* of the system within an organisation and implemented as part of a firm's routines (Nelson and Winter, 1982).

In brief, the EU textile industry should initiate another cycle of fundamental change to create a new competitive advantage away from its current one. In other words, the firms have to *break away* from their traditional *values* and *practices* which may lead them to fall victim to the maturity-trap. The firms are likely to face great challenges due to: the structure and size of the industry, the cost of developing new technologies, the harsh competitive environment, the complexity to manage change and, most of all, a lack of good leadership. These are in fact the factors that hindered radical change in the Lancashire cotton industry argued by Lazonick (1981, 1983) as the major contributor to the decline of the industry. Thus, history has the potential to repeat itself if Europe does not take the necessary action to overcome the problems which impede transformation. As the competitive environment today is significantly more intense, in addition to significantly higher cost technology and more rapid changing of demand than a century ago, the challenge the European textile industry is facing is arguably much greater than the British did in the early 20^{th} century.

This study is highly relevant to the current condition of the EU textile industry as it aims to address such issues. The case studies in Chapter 5, 6 and 7 explain the factors that determine the result of the firms' attempts to initiate the process of de-maturity. The process of change and firm strategy which lead to de-maturity or the maturity-trap are also examined. The results can be used to help firms to improve their innovative capabilities and to support the development of EU strategy and policy for the rejuvenation of mature industries, especially the textile industry.

1.3 Methodology

As discussed earlier and will be elaborated on in Chapter 3, the experience of the British textile industry remains relevant for today's environment although it involves greater complexity. The study of the decline of the Lancashire cotton industry shows that the historical aspects which influenced the evolution of the industry can play a significant role in our understanding of the nature of decline. Thus, historical approach to industrial evolution is the most appropriate approach here. To enable a robust analysis, the case study research method is deemed to be the most appropriate because the dynamic nature of the situation throughout the history involves a large number of variables to be examined, all of which have complex mutually interdependent linkages (Yin, 2003).

The appropriate unit of analysis that can explain the process of change at the necessary degree of detail is the firm level. The experience of the German textile industry suggests that the plight of the industry depends on the innovative capabilities of the firms to radically change every aspect of their organisations away from the maturing or uncompetitive ones. Therefore, a firm level analysis enables us to closely examine the manner in which mature firms fall into the maturity-trap or, conversely, create and improve their innovative capabilities and continuously change to adapt to a changing competitive environment.

The study of business organisation as the determinant of the rise and fall of an industry's competitiveness has rarely been discussed in the study of changing industrial leadership in the textile industry (Mass and Lazonick, 1990). As a consequence of this, the literature has failed to interpret the historical context of the economic decline in the context of firm strategy. It lacks a comprehensive explanation of the inner workings of business enterprises –or the firm level study- that in fact, as a collective action, determines a nation's competitive advantage (Mass and Lazonick, 1990). Indeed, Robertson, *et al.* (2009) suggest that there are only a few studies which have explained the detailed process of innovation. It is very important to understand how firms successfully generate, adopt, use and commercialise new technologies that facilitate the diffusion of the technologies and the context and the environment in which they operate. This would provide the 'missing' link that has been neglected by the government in policy development and implementation as effective innovation policy is a direct function of their understanding of the process.

These arguments suggest that the firm level study is potentially useful in the understanding of the competitive advantage of a nation and the assessment of the efficacy of relevant policies. These arguments fit well with the objectives of the study explained earlier. The firm level analysis can explain in greater detail the factors and processes leading to the maturity-trap or de-maturity and the context and the environment which hinder or encourage de-maturity. De-maturity can be interpreted as the development of new competitive advantage.

To achieve the objectives, this thesis analyses detailed case studies of three firms from three different countries in Europe with varying degrees of success in technological, market and structural transition. Each case study illustrates a different path of firm evolution ranging from a firm that is in serious danger of falling into the maturity-trap to two firms that have successfully bypassed the maturity-trap through different routes. The selection of different national firms is necessary to highlight the country-specific history which influences specific evolutionary paths and unique competitive advantage.

A firm's capability to respond to a changing business environment cannot be built up overnight. Therefore, a rigorous study requires a longitudinal investigation of the process of capability development and implementation. The selected firms have to have a long history of innovative activities. They are selected based on their ability to survive as they have been in business for more than a century. These criteria can give us confidence that their innovative capabilities have been tested over an extensive period of time.

Data are gathered from multiple resources including semi structured interviews with relevant people in the selected firms and industry experts, business history articles and books, scientific journals, the firms' official information and statistical data. Using these interviews and secondary resources each case study was developed independently through an iterative process. To simplify the analysis process, each case study is structured in the same manner. Each case study is analysed using the frameworks discussed in Chapter 2.

1.4 Major Developments in the Global Textile Industry

As argued earlier the historical context of the global textile industry is required to understand the current condition of the EU textile industry. The business history of the industry provides the understanding of the process of and factors that influence the rise and decline of the textile industry in different countries. This section provides the background to major developments in the global and European textile industries and explains why this is highly pertinent to the future of the European textile industry. The lessons from the decline the British textile industry, a once formidable competitor, needs be examined carefully if Europe does not want history to repeat itself in the future.

Changing Industrial Leadership

As mentioned in the beginning of this chapter, the history of the global textile and clothing industry has witnessed at least three shifts in industrial leadership over the past two centuries. Changes in industrial leadership are a feature of a mature industry which is characterised by intensive utilisation of labour (particularly for the clothing sector) and standardised technology, and is driven by price competition.

These characteristics which have led the industry to be regarded as 'traditional' has allowed developing countries to gain a competitive advantage mainly through the exploitation of their abundant (unskilled) cheap labour. Japan, for instance, started its industrialisation during the Meiji restoration era in the 1860s through the establishment of cotton textile production. Its industrialisation was initiated by importing textile machinery from England, training local people which were paid much less than those in Britain and sending a number of businessmen and technicians to learn from the more advanced countries. The country rapidly improved its cotton textile production capability through the development of its own high throughput machinery, the creation of new mixed (high and low quality) cotton yarns to produce better quality yarns at lower cost, and created a vertically integrated industrial structure. In the 1880s the country began to export cloths and by the 1930s Japan had successfully challenged Britain's dominance in the global coarsest cotton textile trade.

In a similar fashion, China has built up its competitiveness in textile and clothing manufacturing. The industry has been one of the main driving forces behind the country's success in export markets since the introduction of its Open Door policy and economic reforms in 1979. In addition to cheap labour, its immense potential domestic markets and its burgeoning middle class have attracted large numbers of foreign investors to build textile manufacturing plants in the country. Industrial capacity has soared and has helped make Chinese products extremely competitive in recent years, but at the same time this has severely reduced profit margins and created problems of excess capacity. In response to the situation the government has outlined plans to rationalise the industry with the elimination of capacity of fabrics manufactured with outdated machinery by 7500 million metres and of chemical fibres by 2.3 million tonnes by 2011.

In the past decade, China has become the dominant power in the international textile and clothing trade. Its share (including Hong Kong) in the world clothing export market increased from 30 to 40 per cent between 2000-2006, while its share of textile exports increased from 19 per cent to 29 per cent during the same period (WTO, 2008). The export market which represented 30 per cent of the total textile and clothing production accounted for €122 billion in 2007, more than double the value in 2000. The industry contributed to seven percent of the country's total industrial value added in 2007 and employed 20 million people. In addition to abundant cheap labour, another advantage China has used to great effect has been to hold down the value of its currency (relative to the US dollar) to prevent major price increases in its export markets (Lau, *et al.*, 2009). These factors have allowed the country to dominate the global textile and clothing trade at the lowest end of the market segment.

China's supremacy was badly shaken during 2008-2009 following the credit crisis which severely hit its main export markets such as the EU, US and Japan. Over capacity which has long been a problem in the industry worsened as the growth of the industry declined by 3.7 per cent between September 2008 and May 2009. Exports in January 2009 were 17.5 per cent less than a year before and imports were down by 43.1 per cent. The appreciation of the currency and rising wages have forced exporters to close factories or move large portions of their production further inland where labour costs are lower. Others have shifted production to other low-cost countries such as Bangladesh, Vietnam and Cambodia (Epstein and Wei, 2008). Since the start of 2008, around half of the total number of factories (which reached thousands) in the world's fastest growing economic region of Guangzhou and Shenzhen have closed down.

This defensive cost-cutting strategy appears to resemble the same pattern of migration of textile producers from New England to the southern part of the US in the 1920s. It is not clear, however, whether this strategy will sustain China's cost leadership in the longer term. Substantial excess capacity built up during the boom period between the 1990s-2000s has very strong parallels with the mistake made by the British textile industry in the mid 19th century which accentuated the latter's decline. In addition, rising wages, high inflation and currency appreciation will increase prices and reduce its relative cost advantage. Although its extensive pool of cheap labour may help the country to maintain its cost advantage and its vast population may help to maintain demand at a reasonable level for the foreseeable future, China cannot afford to become complacent and ignore the possibility that other countries may challenge its leadership. Competition at the lowest end of the market segment has always been considerably more intense than in the upper segments. This exerts enormous downward pressures on costs and forces the industry to continuously rely on cheap unskilled labour and outdated equipment.

Consequently, this has led Chinese firms to produce poor quality products and hindered them from entering premium markets. Moreover, demand in these segments is not immune from changing preferences. Issues concerning the lack of quality, the use of child labour and the environmental damage from the use of outdated equipment may cause demand to shift away from Chinese products (Economist, 2009). An over reliance on the lowest end of the market could prove potentially fatal for Chinese firms as their competitive advantage is not built on solid foundations.

Protectionism

Protectionism in the textile and clothing industry is almost as old as the industry itself (Owen, 1999). Indeed, textile producing countries, regardless of their technological capabilities or the size of their markets, maintain some form of protectionism even up to the present day. Protectionism began during the era of the British Empire during which Britain who, like other European countries, committed to mercantilism. Under this doctrine, domestic industries were protected by tariffs while trade with the colonies were limited to commodities which the mother country needed for its industries. With the Industrial Revolution in full swing during which productivity increased considerably, overseas markets grew in importance as outlets for British products. Under these circumstances, mercantilism was deemed to impede access to wider markets as protectionism affected the growth of the colonies and reduced their buying power. Britain gradually reduced tariffs for cotton products between the 1850s-1860s after which a free trade regime was introduced. Free trade was expected to accelerate the rate of economic growth of the colonies and improve their purchasing power to buy British goods. Britain was the first country to promote free trade, while the US and other European countries remained strongly protectionist.

The British cotton industry experienced exceptional growth under the free trade regime up to 1914. However, increased competition in the domestic market especially from the US and Germany, and in overseas markets mainly because of Japan's invasion of Britain's major Asian markets put the free trade regime under very serious pressure. Additional problems were experienced in countries such as

India and Hong Kong as they started to develop their own indigenous textile industries to meet their own domestic demand. The culmination of problems led the British industry to suffer from severe overcapacity and job losses which forced the government to introduce tariffs in the 1930s. From this point on the liberal trade regime in the global textile industry ceased to exist and was replaced by a protectionist regime that continues up to the present day.

Increased competition from low-cost countries encouraged the developed countries to take collective action to protect their industries. Protectionism in the global textile and clothing industry was institutionalised at the international level with the establishment of the General Agreement on Tariffs and Trade (GATT) in 1947. The institution which was initially created to reduce protectionism was instead used to negotiate greater protection as the idea of freer trade promoted by the US and Canada resulted in major market disruptions in the developed countries. Protectionism against imports of cotton products was introduced through the ratification of the Short Term Cotton Arrangement. This was subsequently followed by the Long Term Agreement Regarding International Trade in Cotton Textiles (LTA) in 1962 (Owen, 1999).

Pressures for even greater protectionism mounted in Europe following the oil crisis in 1973 and the recession that followed. This crisis caused the textile industry in the nine EU countries to suffer from one million job losses, falling profits and investment, and surplus capacity (Dolan, 1983). Excess capacity reached 40 per cent on average (Tsoukalis and Ferreira, 1980). A number of the European countries made an appeal to the European Union (European Economic Community prior to 1993) to expand the scope of protection to include quotas for products made of other fibres (including wool and man-made fibres) in addition to cotton. An agreement was reached in 1973 which was stipulated in the Multi Fibre Agreement (MFA) and signed under the auspices of the GATT.

The MFA was officially arranged to provide the developing countries with guaranteed access to markets in the developed countries without causing overcapacity, considerable (absolute) loss of market share and employment, or 'industrial disruption' in the developed countries. The EU countries agreed to allow a threshold of six per cent growth for the imported product market. The threshold was deemed to allow the European countries to modernise their industries, re-train its textile workers and assist investment that would provide alternative employment for the redundant textile workers. In reality, however, the MFA was a means to discriminate products from the developing countries as greater protection measures were integrated into the agreement throughout the period of protectionism.

The MFA was renegotiated five times before it finally expired in 1994. However, the industrialised countries demanded an extension to allow their industries to adjust (to the condition post MFA). In 1995, four countries (Canada, the EU, Norway and the United States) signed an agreement to gradually introduce trade liberalisation over a 10 year period administered under the Agreement on Textiles and Clothing (ATC). This agreement defined the end of the quota system in December 31st, 2004, but included a clause to allow the importing countries to impose tariffs.

Table 1-1 illustrates the process of integration of textiles and clothing into multilateral trading system on the basis of a country's import volumes in 1990 (columns 2 and 3). The last column shows the growth rate of quotas for products that continued to be restricted during the transition period. In other words, import volumes of the remaining products that were not integrated into GATT increased at each phase by a set percentage.

Date	Minimum volume integrated (percent)	Accumulated volume integrated (percent)	Remaining quota growth rate
01.01.1995	16	16	16
01.01.1998	17	33	25
01.01.2002	18	51	27
01.01.2005	49	100	Full integration

Table 1-1. Integration of textiles and clothing into GATT
Source: Nordas (2004) p. 13

The end of the ATC did not necessarily end the protectionist regime, however. The EU and the US re-imposed quotas in 2005 against Chinese products based on the argument of industrial safeguard permitted by the World Trade Organisation (WTO) in the event of a surge in imports which may harm the importing country's industry. Under these circumstances, the WTO allows its members to restrict imports temporarily to safeguard their domestic industry. The argument made by the EU to impose the new quota restriction was similar to that to impose ATC, that is, the industry 'deserves' temporary protection to adapt to the quota-free environment. Up to 2007, the US and EU markets had been protected under a number of quota-based safeguard arrangements with China. Throughout 2008, a surveillance system was implemented to replace the quota system after which all quota restrictions were removed in 2009. However, the transitional product-specific safeguard mechanism remains an option until December 11, 2013 in case of any major market disruption in the importing countries caused by a surge of imports from China.

Protectionism may have slowed down the decline of the textile industry. However, it did not halt imports or contribute to the improvement of competitiveness of the EU textile industry in the traditional market (clothing and textile clothing markets). This can be seen from the trade data which shows that imports grew significantly despite the protectionist regime. Between 1973-1980, imports from non EU countries increased by 110 per cent (Toyne, *et al.*, 1984). In more recent years EU clothing imports have increased by around 260 per cent (in terms of value) between 1988-2002 whereas the textile sub-sector performed better although the import shows an upward trend as illustrated in Figure 1-1.

The textile sub sector has been saved by the growing market of high value added textiles for technical applications. China's clothing exports to the EU alone grew at an annual rate of 20 per cent between 2000-2006 and 12 per cent globally, while imports from all other countries to the EU increased by 10 percent. In a similar fashion, the annual export markets from China and India to the US increased by 24 and 11 per cent respectively between 2000-2006, while US exports increased by only 2 per cent (WTO, 2008). The growth rate of China's export market to the US grew by 18 per cent annually in the same period.

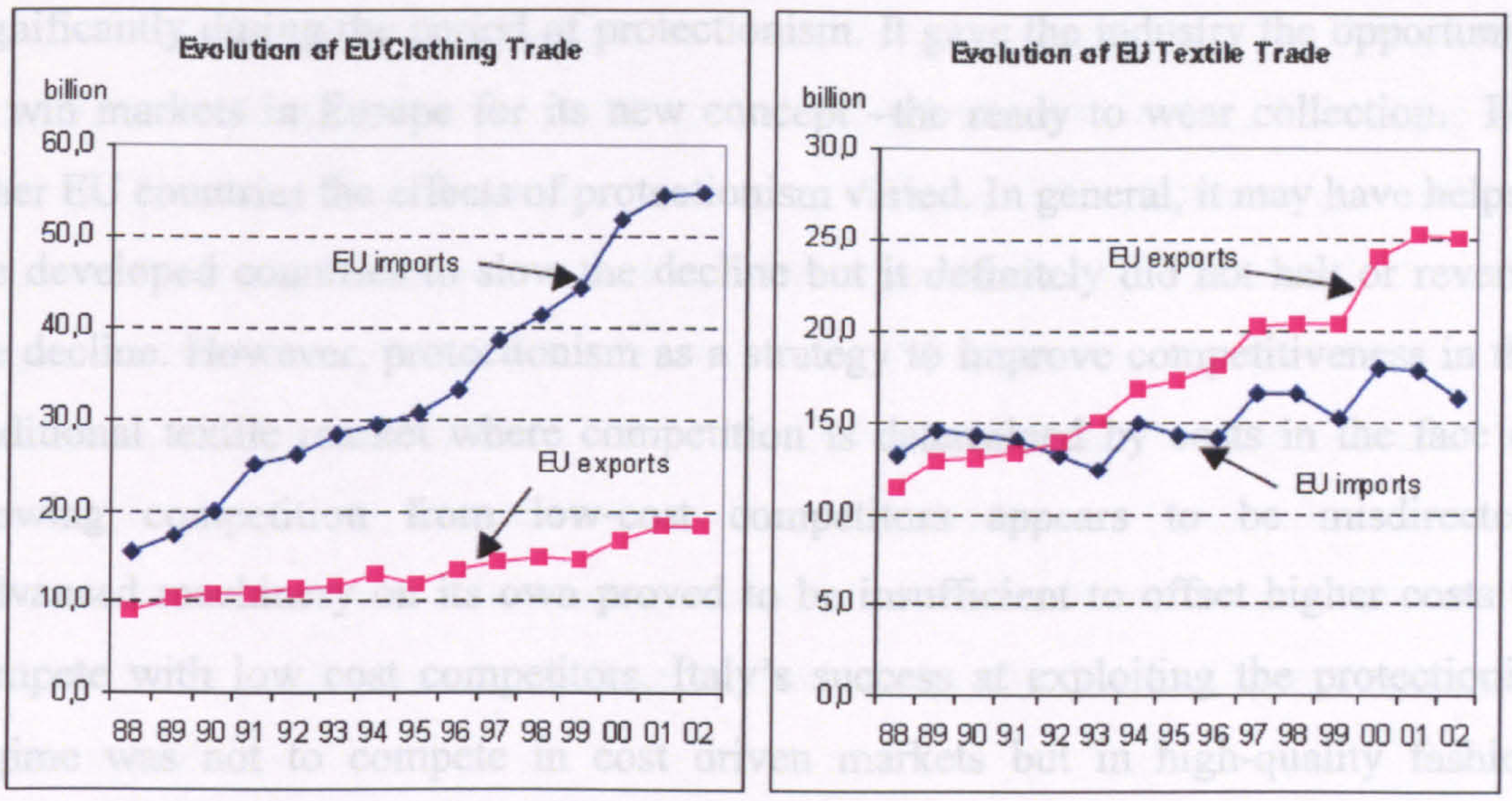

Figure 1-1. The Evolution of the EU Clothing and Textile Trade (1988-2002)
Source: Commission of the European Communities Working Paper no 1348 (2003) p.9

It appears that despite being given 30 years of protection as well as opportunities for industrial adjustment the EU and other developed countries in general failed to restore their competitiveness in the traditional textile market. The literature has placed the blame on the inability of the European Commission in dealing with the different stances among its member countries[1] which led to the ineffective application of the MFA (see for example Dolan, 1983, Tsoukalis and Ferreira, 1980). It appears the EU's major mistake was to use protectionism to preserve an uncompetitive industry rather than to promote and drive radical change to generate a new competitive advantage. For example, the majority of government funds were not used directly for rationalization and restructuring, but to subsidise prices with no accompanying plan for long-term growth (Tsoukalis and Ferreira, 1980). Although attempts were made to rationalise and modernise the industry which resulted in a significant increase in labour productivity by 25 per cent between 1973-1979, these were not sufficient to arrest, let alone reverse the flow of imports. The condition worsened as investment fell considerably in 1979 whose level was only two-thirds of that in 1973.

To conclude, protectionism itself may be necessary to protect the economies in transition. In fact, as discussed in the next section, the Italian textile industry grew

[1] The EU countries were divided between two opposite stances in the negotiation and application of the MFA. The division included the protectionists -Britain, France, Ireland and Italy- and the less protectionists – Germany, the Netherlands and Denmark. In those countries, considerable restructuring and rationalization had already occurred since the 1960s (Dolan, 1983).

significantly during the period of protectionism. It gave the industry the opportunity to win markets in Europe for its new concept –the ready to wear collection. For other EU countries the effects of protectionism varied. In general, it may have helped the developed countries to slow the decline but it definitely did not halt or reverse the decline. However, protectionism as a strategy to improve competitiveness in the traditional textile market where competition is determined by costs in the face of growing competition from low-cost competitors appears to be misdirected. Advanced machinery on its own proved to be insufficient to offset higher costs to compete with low cost competitors. Italy's success at exploiting the protectionist regime was not to compete in cost driven markets but in high-quality fashion markets where the basis of competition is design and quality. In retrospect, the EU textile industry should have focused its efforts on taking advantage of the opportunities open to it in the higher value added textile market and where it could build and establish a long-term competitive advantage. Unfortunately, this did not happen and the majority of the textile and clothing firms continued to produce uncompetitive traditional products and service traditional markets which precipitated the industry's long-term decline.

1.5 Europe: The Decline of a Major Competitor

As mentioned earlier, the textile industry in Europe, notably Britain, had dominated the global cotton textile trade for over a century during the 19^{th} century up until 1914. The country's old and large textile industry was unable to respond sufficiently to the emergence of new competitors who offered significantly lower-cost products. The industry lost 40 per cent of its Asian market to Japan in 17 years. The British government's solid support for free trade which had helped the industry to gain a dominant position up to 1914 became shackled and the industry suffered greatly. Other European countries were less affected through the introduction of high tariffs. Britain's hegemony in the global textile trade started to erode in 1914 after which it needed trade protection to stop imports which dominated its domestic and overseas markets.

Between the 1970s-1980s, the European textile industry underwent a painful readjustment to combat the harsh competition from low-cost competitors such as

Hong Kong, South Korea, Singapore, India, Pakistan and Indonesia. Europe lost around one million jobs in the textile and clothing industries in the 1970s alone and 4600 (15 per cent) firms went into bankruptcy (Dolan, 1983). Britain alone suffered yet another setback as employment shrank by 30 per cent and production declined by 30 per cent between 1963-1978 (Toyne, *et al.*, 1984). Germany suffered the worst among the European countries in terms of employment with a decline of around 44 per cent and lost 32 per cent of its firms. However, the country managed to minimise the decline in production to only six percent. Meanwhile, Italy saw employment fall by 25 per cent yet the country managed to increase production by 15 per cent during the same period.

The different outcomes among the EU countries despite the common trade policy were influenced by the different nature of the policies towards industry adopted by each country[2]. The difference was affected by the different nature of the crisis faced by each of the member states. As a result of this, market specialisation emerged in different countries. In the 1980s Italy replaced Britain as the leader in the European textile industry with 11 per cent share of the global textile clothing market. The country gained its competitive advantage through specialisation in the high-end fashion textile market. Germany, the second largest textile producing country in the EU, emerged as the global leader in the technical textile market. Both countries avoided markets where competition was driven by costs and preferred to choose alternative routes where they could each build up a competitive advantage. Italy built up a competitive advantage in product quality and design and Germany in technological performance. Up to the present day, Italy has maintained its leading position in Europe. It represented 25.5 per cent of the EU's total textile and clothing turnover and 37 per cent of the total number firms in the sector in 2006, while Germany trailed behind with 19 percent of total EU turnover.

Italy's relative superior performance compared to the other EU member states was driven significantly by its aggressive adoption of new manufacturing methods and technologies in the 1950s supported by the US and its Marshal Aid Programme (White, 2000). By 1964, 86 per cent of the Italian mills had adopted fully or semi-automatic looms compared with 37 per cent in Britain and 69 percent

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[2] Since the 1970s the EU member countries had to construct trade policy collectively but industrial policy remained prerogative of individual member countries (Dolan, 1983).

in France. Productivity increased by 350 percent and 400 percent for spinning and weaving respectively during this period (Antonelli and Marchionatti, 1998). Italy became one of the most progressive cotton industries in Western Europe, with 60 per cent higher of productivity rate than that of France and Britain in 1987.

In addition to the adoption of modern technology, Italy's domination of the high-end fashion market is supported by the long standing relationships between textile manufacturers and fashion designers dating back to the 1940s and by its creative capability built up over the years to satisfy its domestic and European market which demanded stylish, high quality and fashionable products.[3] The relationship allowed designers and textile manufacturers to work together to continuously create new designs and to improve product quality. The Italian textile industry started to grow rapidly prior to and during the Second World War. During the period, exports from other European countries to Italy, particularly from France, the leader in the high-end fashion market at the time, were blocked. This provided opportunities for local manufacturers to gain market advantages and encouraged new designers to emerge (White, 2000). As opposed to France which was prominent with its *couture* (ready-to-make) tradition, Italy, supported by its high throughput machinery from the US, transformed its couture capability to pioneer the trend of the *prêt-a-porter* or ready-to-wear collection led by Benetton in the 1970s. This new concept allowed them to capitalise from the combination of fashionable products and large scale production. In so doing, Italy avoided price sensitive product lines but at the same time escaped competition with France in the couture market. This innovative development became a trend worldwide and led to a shift of power in the textile and clothing supply chain away from manufacturers to designers.

It has been argued Italy's distinctive industrial structure has been the key factor that supports its success in the ready to wear collection. The industry is characterised by a large number of small, family-owned firms with high levels of inter-firm collaboration and are clustered in districts concentrated on particular segments such as Prato in wool textiles and Capri in knitwear (Porter, 1990, Owen,

[3] In contrast to Britain, Italy did not possess large colonies as the market of cheap textile products. Since its market has been predominantly for domestic and European consumption characterized with higher quality and variety, the Italian textile industry has built up its design capability and flexible manufacturing systems. The market was very different from the main market of the British textile industry which demanded standardized and cheap products.

1999, Guercini, 2004). The high degree of co-operation among firms in each network stretches right across the supply chain. The structure allows for flexible production systems a pre-requisite to compete in the fashion market where short production runs and rapid responses to changes in demand is the norm.

The experience of Germany in building up its capability in high-tech technical textiles is somewhat different to that of Italy. In contrast to the Italian, British and French governments, the German government opposed the idea of protectionism. The country led the coalition (together with The Netherlands and Denmark) to reject the MFA and instead preferred restructuring and rationalisation including outward processing as a means to maintain competitiveness. Germany found that protection would impede its growth as 40 per cent of its products were exported and 75 per cent of outward processed products came from Germany. Although the country finally accepted the terms of the MFA, its industrial policy showed its liberal stance relative to other EU countries. In contrast to the British government policy which protected uncompetitive firms, German government policy forced the industry to rapidly adjust to the new competitive environment and forced the uncompetitive firms to leave the business. The restructuring and rationalisation programme which started in 1963, much earlier than the other European countries, helped Germany to achieve the highest productivity in Europe, which increased by 60 per cent between 1970-1986 (Nelson, 1987). Such a significant rise in productivity permitted the country to compete favourably with low-cost competitors.

Germany understood that outward processing was only a temporary measure as increased wages in the production countries were inevitable. Nevertheless, the strategy allowed the industry to retain its current competitiveness while necessary adjustment was underway. Outward processing also forced the old, uncompetitive firms out of business and left the industry with capital intensive firms. This paved the way for a rapid adoption of more modern technologies in which the industry invested heavily (the fourth largest in the world in the early 1980s). Interestingly, the capital intensity of the textile industry, that is, capital stock per worker, was higher than for any other manufacturing industry (including automotive and machine tools) in Germany between the 1970s-1980s. This suggests that the industry has progressively reduced its labour requirements.

In addition to improvements in productivity, the German textile industry also pursued a product differentiation strategy by moving up the value chain to replace the increasingly uncompetitive mass produced textiles from the mid 1970s. The industry built up new capabilities in higher value added products for high fashion goods and technical textiles. The underpinning factors that supported such a transformation was the close proximity to EU markets (the main market for high fashion and technical textiles); an extensive number of highly flexible mid-sized firms which were large enough to invest in modern machinery and flexible enough to respond to changing demand; and a high quality workforce. The latter was supported by the country's well-organised vocational systems which permitted sufficient skilled workers to be produced every year to rapidly adopt new technologies and to operate, maintain and repair machinery. The trained workforce also allowed the industry to undertake quality improvement activities and to progress the transition towards flexible production systems. Equally important was the firms' collective action in research and promotional programmes to jointly solve problems which emerged during the transformation process (Nelson, 1987).

The specialisation among the EU member states increased in its variety along with the enlargement of the Union. The integration of the Southern European countries in the 1980s and the Eastern European countries in the 2000s extended the fragmentation of the EU textile markets. The Northern and Western parts of the region have significantly shifted their textile capabilities to higher value added textiles for technical and industrial applications whereas the Southern and Eastern European countries largely remained producing textiles for clothing and household markets. Within the latter sub-region Italy concentrates on the high-end textile market segment, Spain and Portugal on the middle segment with the rest on the lower segment. For the traditional textile and clothing industry, such a structure favours outward processing due to the proximity between production and markets. The increasing tendency for preferential agreements among the EU countries that permits imported products duty free is another advantage of the enlargement. For the technical textile sector, the new member countries are attractive places to relocate the production of products that are on the verge of saturation on the ground of cost. The enlargement is also advantageous for market expansion of niche products as the size of the EU textile industry is too large to rely on niche markets. The sector needs to sufficiently broaden its market base to generate sufficient revenue to finance innovation more generally.

Arguably, the EU textile industry is unique in that a broadly fragmented market structure exists in one large economic area. The industry encompasses the manufacture of fabric, apparel and leather goods made of various fibres for traditional, home furnishing and high-technology markets. Up to the present day, the clothing market stills occupies the largest share as shown in Figure 1-2, while the technical textile market although it accounts for the smallest share has been growing at an annual rate of four per cent.

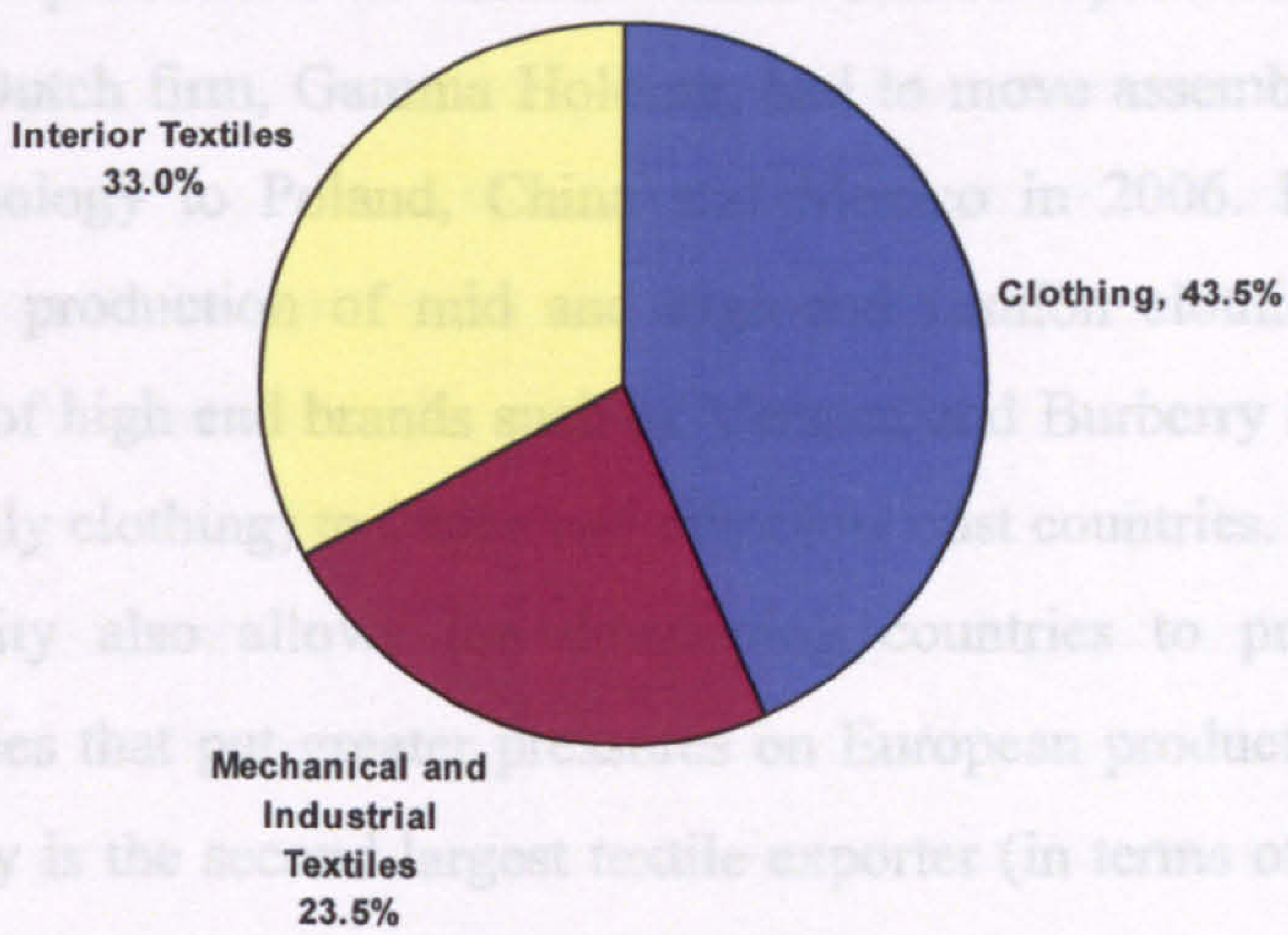

Figure 1-2. Market structure of the European textile products (2003)
Source: Euratex-CIRFS

Enlargement and specialisation has not stopped the European textile industry from continuous decline in terms of output, employment and turnover as mentioned earlier. Thus, although the fragmentation creates unique industrial dynamism within the economy the efficacy of such a structure to improve the competitive advantage of the EU textile industry in the long run is not obviously clear. Without a doubt, the structure favours the general trend of outward processing as the movement of goods within the EU countries is duty free. Nevertheless, as demonstrated by the experience of the German textile industry outward processing is only a temporary strategy to cut costs as an increase in costs in the production countries will eliminate any cost advantage. This is already apparent in the major destinations of outward processing in the EU, mainly the Czech Republic and Hungary. Textile employment in both countries declined by 50 per cent between 2000-2008 as wages increased which reduced their cost advantage (Sura, 2009).

The fact that the industry has been in relative decline over the past decade, including in Germany and Italy, may indicate that the market for higher value added textile products developed in the 1960s-1980s have reached maturity. This has forced the European textile firms to transfer the production of once high-value added products overseas. For example, the production of geotextiles, one of the earliest innovations in technical textiles which once saved the Dutch textile industry, increased significantly in China in recent years. The Dutch firm, Ten Cate, have moved its geotextile production to China which started operations in 2008. Meanwhile, another Dutch firm, Gamma Holding, had to move assembly activities of its filtration technology to Poland, China and Mexico in 2006. In a similar fashion, the overseas production of mid and high-end fashion clothing products increased. A number of high end brands such as Versace and Burberry have moved their production (mainly clothing) to China and other low cost countries.

Market maturity also allows the developing countries to produce rival products at lower prices that put greater pressures on European products. Although the EU textile industry is the second largest textile exporter (in terms of value after China) history shows that being large is not sufficient to maintain a competitive advantage in the face of changing markets and technology. Therefore, the industry urgently requires innovative solutions, probably radical ones, to find a more sustainable competitive advantage to survive and grow in the long run and avoid a similar catastrophe to the one experienced by the British textile industry.

The New Paradigm

Despite the decline, the industry remains an important element of the EU economy, representing four per cent of added value manufacturing and nine per cent of manufacturing employment in 2006. Therefore, the industry cannot be neglected. The EU has realised that its protectionist policy and cost reduction strategy (by means of outward processing) cannot provide the foundation for sustainable competitive advantage. It has recently made a fundamental shift in its policy away from the short and medium-term protectionism to long-term technological innovation driven programmes. The launch of the European Technology Platform as mentioned earlier is the first major initiative to create a new period of growth through industrial transformation from a traditional to a knowledge-based industry. The initiative involves new approaches in R&D and innovation; education, training and social issues; environmental issues and consumer protection; intellectual property rights; and cooperation with Mediterranean countries to allow production relocation and outward processing. Among those programmes, research and innovation has shown the most rapid progress. The government provides funding at the national and regional level for R&D (through collaborative research) and the adoption of modern technologies. In this respect, the EU has set out a Strategic Research Agenda which covers three principal areas of concentration: a shift from commodity towards speciality products through the development of new specialised fibres, materials and production processes, functionalisation of textiles; the creation of new textile products for diverse applications and the creation of new markets; the development of mass customisation and personalisation of products through new approaches in design, production process and technology, logistic and distribution, and supply chain. Up to the present day, 31 research projects involving 400 organisations (private firms and research centres) and €160 million government research funding between 2007-2009 have been created.

This attempt to transform the industry appears to be a huge mountain to climb. As mentioned earlier, the industry which is predominantly populated by small and medium-sized enterprises have *low innovative capabilities, questionable management capabilities and suffer from a lack of financial resources.* To make matters worse, the majority of large firms in the industry are of a traditional nature. This can be seen by the low level of productivity compared to other manufacturing sectors (Johansson, 2008). Therefore, the firms may find it very challenging to create competitive long-term strategies and manage change. The British experience suggests such a structure and characteristics of firms can seriously impede fundamental change (Lazonick, 1983).

Technological leadership alone is by no means sufficient to achieve sustainable competitive advantage. As Pavit and Soete (1982) argue that whilst technological capabilities provide greater opportunity for industrial leadership, it is the rate and level of diffusion of the technology into economic use and the market monopoly and profitability which determine the competitiveness of a nation. They believe that the dramatic change in the fortunes of the British textile industry was largely driven by the slow diffusion of the British technologies into the domestic market amid rapid international diffusion of the technologies, the latter of which enabled other countries to catch up and eventually surpassed Britain's capabilities. As the international diffusion and imitation of technology is inevitable, the argument suggests that the leading countries should not only lead the development of new technologies but also lead the diffusion and commercialisation of new technologies and the creation of new markets.

Indeed, it is the major weakness of the European textile industry and other European industries in general. Colombo (1977) who identified the different characters of industrial innovation between the US, Japan and Europe found that Europe with its long tradition of scientific research was relatively weak in relation to its competitors to direct research in universities towards industrial development. In other words, Europe's lack of entrepreneurial spirits has resulted in its lagging in the commercial exploitation of technologies and weakness in product development. The failure of Courtaulds to maintain its advantage as the first-mover in the commercialisation of carbon fibres is a useful example. The firm which used to be the largest carbon fibre producer in Europe in 1970s-1980s pursued high volume markets (sporting goods and military applications) and refused to diversify into niche markets. Its position in the sporting goods market was challenged by low-cost competitors (particularly Japanese firms), while its military market disappeared following the end of Cold War in 1991. Under these circumstances, the poor return it received from its large investment which stemmed from its attempts to establish a significant presence especially in the US military market, forced the management to sell the business in 1991. Its high capacity made them reluctant to find markets in small emerging markets. Ironically, the acquirer, RK Carbon, was successful in the market through its diversification into several niche markets including break pads. Its main competitor, Toray, was a follower in the market, has become the largest carbon fibre manufacturer as it offered better technology (zero impurities) a critical requirement in high-value added markets, a route that was ignored by Courtaulds. This suggests that despite the lessons, the EU textile industry appears unable to respond rapidly to a changing competitive environment, particularly when it involves radical change.

1.6 Structure of the Thesis

The thesis is structured as follows. Chapter 1 provides the background of the global textile industry and the position of the European textile industry in the global textile trade. The story of the rise, fall, specialisation and fragmentation of the industry is presented from which the argument of this thesis, that is, to challenge the conventional assumption about traditional industries, is built. Chapter 2 presents a review of the relevant literature which underpins the argument. This covers the topics of innovation and the economics of technical change, business strategy, particularly industrial maturity and de-maturity, path-dependence of technological change and lock-in into the existing structure, dynamic capabilities and the open innovation. Chapter 3 discusses the debate about the decline of the British cotton industry. Various scholars have identified a number of factors that cause the decline, all of which gravitate towards the 'irreversible' decline. The analysis here is used to develop the argument of de-maturity or 'reversibility' of the European textile industry.

Chapter 4 discusses the impact of technological change on the development of the textile industry. The analysis focuses on the science and technologies which have great (radical) impacts on textile technologies, products and markets, that is, polymers technology and advanced materials. This chapter shows that the development of technology in the textile industry is indeed very dynamic. This supports the argument to challenge the conventional wisdom/assumption about the maturity of technological development in the industry.

Indeed, this study finds that a number of traditional textile firms have radically changed their technology, market and organisational practices, and managed a *long period of transition* to become technical textile producers. For all intents and purposes, these firms have initiated the process of de-maturity and escaped the maturity-trap. The *three case studies in three different European countries* illustrate different paths of firms' evolution ranging from: a firm that is in serious danger of falling into the maturity trap; and firms that have successfully bypassed the maturity trap. The selection of different national firms is necessary to highlight the country-specific history which influences specific evolutionary paths.

The lessons from the decline of the British textile industry and the failure of one of its major players, Courtaulds, indicate that rapid changes in a mature industry are often problematic. To achieve the balance between incremental and radical change often involves a very complex process. The complexity and the process of change at the firm level are discussed in greater detail in each of the case studies presented in Chapters 5-7. The case studies reveal that whilst technological capability is the key determining factor of competitiveness, entrepreneurial organisation and good leadership are equally important to sustain competitive advantages because they determine the rate and direction of innovation and change at the firm level. Chapter 8 draws the conclusion and policy implication of the study.

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2

Literature Review
The Textile Industry: A Question of Survival

2.1 Introduction

This chapter reviews a broad range of literature that provides the necessary theoretical framework to analyse the transformation of the European textile industry. The framework provides the foundation for the central issue of this study, that is, to explain the manner in which *mature* European textile firms have; 1) failed to retain their leadership; and 2) survived and, moreover, prospered —although they have experienced enormous economic and technological changes especially during the 1930s, 1970s and 2000s. The relevant literature intertwines the economic, innovation and management fields and is divided into four sections. The first two sections present the theories that are fundamental in our understanding of industrial maturity and the causes of the maturity-trap. The first section discusses the process of maturity and factors that contribute to the maturity-trap. In this section, the cause of the decline of the British cotton industry is explained using the maturity and maturity-trap framework by Abernathy et al. (1983). The implication of path-dependence in technological change and in the evolution of organisational capability and its effects on the maturity-trap or inertia are explored in the second section. The third section reviews the literature relevant to the phenomenon of de-maturity. This concept is the most appropriate for analysing the transition of the European textile industry from a mature to a knowledge-based industry. We use the industrial de-maturity framework by Abernathy et al. (1983) as the conceptual framework.

Although the framework was originally applied to analyse the US automotive industry between 1900 and 1979, Abernathy et al. (1983) indicated that the framework should also be applicable to different industries.

The fourth section concerns a framework which discusses a shift of innovation paradigm in high-technology industry. The framework, the Open Innovation Paradigm (Chesbrough, 2006), provides the basic understanding of innovation paradigms that should be adopted by firms to compete in a rapid changing business environment in the 21st century. The framework is useful to analyse a shift in innovation paradigm experienced by a number of textile firms in Europe, from being entirely dependent on their suppliers prior to the 1970s to strategically placing research and development as the major source of competitive advantage.

The thesis of maturity and de-maturity examine provide the analytical framework for our basic argument. However, they do not provide ***sufficient explanatory foundation*** for the process or the nature of continuous change in technology, markets and organisation undertaken by innovative firms aimed at shifting the competitive factor away from cost reduction to product performance or technological leadership. The last section is dedicated to review literature that complements the de-maturity and the open innovation paradigm frameworks to explain the transformation process at the firm level. This discussion emphasises the dynamics of organisational capabilities in their responses to dynamic environments.

2.2 Industrial Maturity and the Maturity-Trap

Industrial maturity has been studied by a number of economic and business historians (see for example Vatter, 1975, Abernathy and Utterback, 1978, Abernathy, et al., 1983, Owen, 1999). It occurs as a consequence of dynamic relations between market share, competition and technological advancement. According to Abernathy and Utterback (1978) at the early stage of industrial evolution (fluid phase), production flexibility is critical to deal with a number of factors such as uncertainties in market demand and technology, instability of supply and possible frequent major changes in products. Uncertainties force firms to invest in rather small scale plants or development projects to reduce the risk of undefined markets and products.

Competition is determined by functional product performance rather than costs. Therefore, innovation attempts emphasise on product development rather than process improvement (Figure 2-1). The moment market demand is well understood and product features and attributes are defined, a dominant design emerges (Anderson and Tushman, 1990). At this stage, firms begin to shift their innovation activities from product development to capacity and market expansion through the adoption of modern and capital intensive production systems –or process innovation- and the implementation of complex organisational structure (transitional path). Thus, innovation becomes incremental in nature. The diffusion of knowledge and know-how facilitates the growing number of competitors (imitators). Growing competition and/or slowing market growth forces firms to improve efficiency in order to improve productivity and reduce costs through economies of scale. At this stage the industry is heading towards the mature stage. In short, the process from the development stage to the mature stage is often referred to the industrial life cycle.

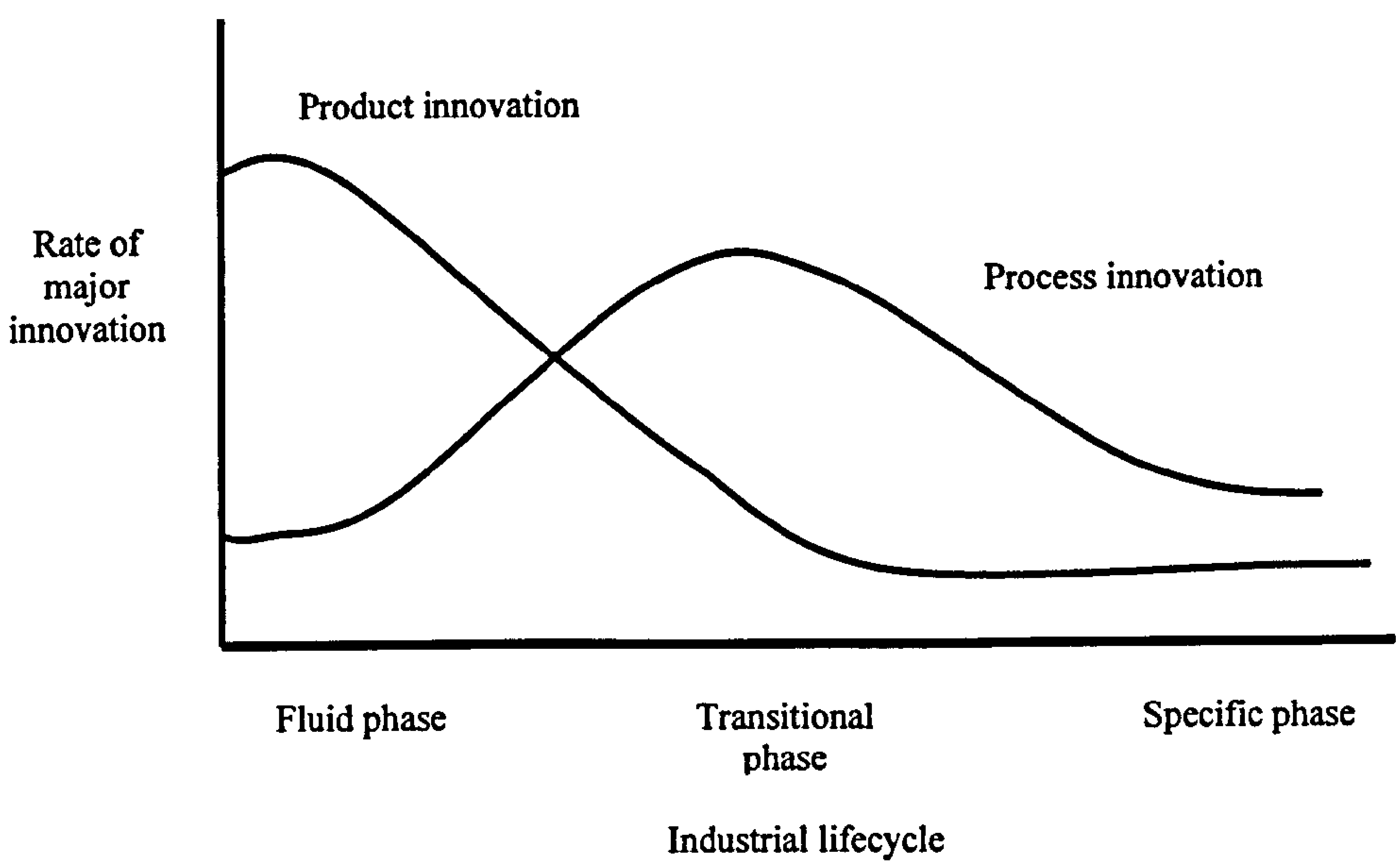

Figure 2-1. The dynamics of innovation- the shift from product innovation to process innovation during the transition towards maturity
Source: Utterback (1994) p.xvii

In a mature industry, the relationship between demand and technologies to fulfil such demand has been established and widely understood. Competition is very intense as the barriers to entry are sufficiently low to permit new entrants. All players perceive competition in the same manner and follow the same strategy to compete with one another. The nature of competition shifts from being driven by technological or product performance to by product appearance, market share and efficiency to improve productivity (Styles and Goddard, 2004) that affect costs.

Such a pattern of industrial innovation can be exemplified by the development of nylon. In its early development stage, the production was performed within a small scale plant in which a series of trial and error of product development for a number of different markets were undertaken. The first market for nylon was the toothbrush. From this market DuPont, the owner of the technology, learned to improve the process technology and searched for other potential markets. The firm found the technology had the potential to substitute silk fibres in the women's hosiery market. It started to develop the processing technology to produce nylon filaments which suited the requirements for knitted stockings. Following intensive market research and product development to define market needs and the most efficient production processes the firm built larger production plants to increase production capacity and improve efficiency. This allowed the firm to increase its market share. Following the expiry of the related patent which permitted other firms to produce similar products for the same market, competition intensified. As market demand was well understood and the technology and the relevant know-how were widely accessible, the basis of competition shifted to costs. At this point, the market was moving towards the mature stage.

Low cost products can be achieved through the utilisation of large volume production processes. This requires a set of equipment operating in a standardized, automated system. The equipment undertakes a series of tasks and reduces the need for highly skilled labour and can be purchased off-the-shelf. Under such circumstances new competitors from low-cost countries with abundant low-skilled labour can enter the same market. Barriers to entry which at the earlier stage rest on technological competence shift to, among other things, the magnitude of initial capital, market share controlled by the existing players and, in some cases, proximity to markets. The developed countries start to receive pressures to reduce costs to adapt to the new competition brought in by new low-cost competitors. Consequently, producers in developed countries are forced to relocate production facilities to countries that offer cost advantages.

The development of textile machinery follows such a pattern. In the early development of textile spinning and weaving machinery, spinning jenny, mules and flying shuttle looms were considered to be high technology as they replaced aspects of manual work. They were flexible, being able to spin and weave different standards of quality of cotton fibres. Skilled labour was required to operate the machines. Attempts to standardize textile production began when an American, John Thorp, invented ring spinning in 1828. He invented equipment that can replace skilled labour so that the equipment could be operated by less-skilled labour. Innovations in textile machinery that followed placed greater emphasis on automation, high speed and throughput, and moved towards mass production. The economic boom following the Second World War which encouraged consumerism in the US facilitated the fast growth of global demand. This facilitated the diffusion of the mass production systems to Europe and, eventually, to other parts of the globe.

The widespread diffusion of the machinery allowed low-cost countries with abundant low-skilled labour to enter textile and clothing markets. It encouraged Japan, India, and, later on, Hong Kong, Indonesia, Pakistan, China and North African countries to build up textile production capabilities. Fierce competition from the new competitors forced a wave of relocation of clothing and textile production from the Western countries to Asia and North Africa which started in the 1970s. Such a development has encouraged the globalisation of textile and clothing production in which the developed countries can source products from other parts of the globe. This situation has put greater pressures on the European textile and clothing firms to a point where they were forced to become service firms which only design and market the products.

Industrial maturity is not only a consequence of the relationship between changes in technology, market share and competition. According to Hayes and Abernathy (1980), it is also a consequence of managerial failure -both vision and leadership. They argue that the management principles that favour ***short-term cost reduction*** rather than ***long-term development*** of technological competitiveness can gradually erode the propensity and the capacity of firms to innovate. This approach prioritised short-term incremental improvements at the expense of more risky R&D projects that may need several years to generate profits but may provide a new long-term competitive advantage. The behaviour is a result of a heavy reliance on control over short-term financial measurements (return on investment, ROI) which drive the management to become more and more adverse to risk. This is argued to be the cause which led to the decline of the competitiveness of the American manufacturing sector in the 1970s.

Hayes and Abernathy's argument concurs with a number of studies concerning the decline of the Lancashire cotton industry. Lazonick (1983), Lazonick and Mass (1990) and Owen, (1999) suggest that the decline was indeed a result of myopic business strategy and organisational inertia. Lazonick argues that entrepreneurial failure, that is, managers' inability to alter business constraints or to break barriers to change to create new profit opportunities amid fierce new competition from low-cost countries, was a major factor that led to the decline. Managers could not appreciate the need to change and diversify into different markets where their key capabilities were competitive. Instead, they remained in the business which had lost its competitive advantage and continued to implement the same strategy which was no longer suitable to a new environment. Management was not able to escape from or alter the situation (the emergence of cost competition and low-cost competitors) as it perceived as given. Consequently, the firms were locked-in to the existing structure, technology and market. Meanwhile, Owen suggests that misdirected strategy –using an outdated strategy to be applied in a new business environment - orchestrated the demise of the industry. Their arguments indicate that the industry's rigidity is a result of structural problems, in which it favours a familiar strategy, market and technology although the competitive environment has changed.

Sull (2000) names such behaviour 'active inertia' while Levitt and March (1988) refer it to the 'performance-trap'. It is an unintentional tendency among management to reinforce the status quo by its actions in response to competition, particularly in mature markets. Leonard-Barton (1992) suggests that such inertia could be a consequence of deeply-rooted 'core capabilities'[1]. These capabilities, built on past successes and have become the firm's core competence, can cause organisational inflexibility in a changing environment. In addition, Lieberman and Montgomery (1988) suggest that such inertia may be caused by lock-in to a specific set of fixed assets or by unwillingness to close down existing product lines.

[1] Knowledge sets that distinguish and provide a competitive advantage and comprise of four dimensions: 1) technical systems, 2) managerial systems, 3) knowledge and skills, and 4) value and norms, all of which are associated with the various types of embodied and embedded knowledge, and with the processes of knowledge creation and control (Leonard-Barton, 1992).

When an industry matures, the infrastructure and business networks become large and complex so that fundamental changes become extremely costly and risky. At the firm level, as firms grow and mature their organisational functions, routines and production processes expand and the relationship among those factors become more complex. As these interrelationships have been accumulated and are deeply-embedded in the firms over a long period of time the scale of change required to shift the business has increased. Under such circumstances, firms tend to favours their established technologies, markets, production systems and structure in their pursuit for improvement rather than radically restructuring the established system. Abernathy et al. (1983) name such a phenomenon the 'maturity-trap' –an inability or unwillingness among managers or business owners to fundamentally change business practices. Although Abernathy et al. (1983) refer to a lack of entrepreneurial leadership and organisational capabilities as factors that affect the maturity-trap, the study *did not examine* these aspects further. For our purposes here, a *new interpretation* of the maturity-trap is required, wherein an organisation not only favours established products and production processes in its search for improvement, but also has great difficulties to break away from the established culture, routines, skills, knowledge, and internal and external relationships.

The maturity-trap is argued to be the major factor which caused the loss of the British textile industry's competitiveness in the 1930s and the failure to restore it in the 1970s. The industry has been under immense pressures since the First World War because of the emergence of the Japanese textile industry which offered similar quality products at much lower prices. Rather than seeking new sources of income through the creation of new products for new markets, the industry opted for cost reduction strategy (prior to 1970s) and mergers and acquisitions for market consolidation (Owen, 1999). The industry in general neglected radical change despite the fact that its traditional competitive advantage had eroded.

More alarmingly, the maturity-trap does not only affect firms operating in the traditional textile market but also those in the technical textile market. As will be discussed in Chapter 3, Courtaulds' failed diversification attempts in synthetic fibres and carbon fibre show that indeed the firm made significant efforts to adopt and commercialise new technologies. Its failure rested on its decision to use the same strategy and organisational structure which were used to be successful in the development and commercialisation of viscose and acetate fibres. Furthermore, its short-termism caused the firm to make poor business decisions to gain short-term profits in the emerging carbon fibre market. The firm pursued large volume, lower value-added markets (the market it understood better through its main rayon business) and neglected high value added products for niche markets. This led to the demise of the once largest carbon fibre producer in Europe.

2.3 Path-Dependency

The *path-dependent* and *lock-in* phenomena in studies concerning economic change has widely been discussed following the publication of the economics of QWERTY (David, 1986) and the effects of positive feedback and increasing returns in competing technologies on the lock-in phenomenon (Arthur, 1989). Through a narrative economic history of QWERTY, David asserts that history matters in economic evolution such that 'historical accidents' or temporally remote events may have significant influences upon the eventual outcome. With this approach, David postulates that it is feasible to interpret which changes are the most influential to the development of a particular path. The relationships could form 'cause and effect' interactions in a dynamic system, or 'soft determinism' - historical events make pathways in certain directions more probable than in others (Rosenberg, 1994). Among the studies on path-dependency (see, for example Arthur, 1989, Rosenberg, 1994, David, 1994), those that discuss path-dependence in technological change (Rosenberg, 1994) and organizational evolution (David, 1994) are particularly relevant to this study. Rosenberg (1994) argues that the key factors that influence the direction of technical change at one point are the *stock of technological knowledge (or the spectrum of technological options)* and *economic forces*. The former is determined by the presently available scientific knowledge is built on the previously available scientific knowledge and technologies. The economic forces influence the decision to undertake a search process in a direction that is foreseen to have significant potential demand in the future.

One implication of the path-dependent concept is the country-specific market (specialisation) identified in the EU textile industry. The Italian textile industry built its textile competence on its unique structure, close relationships between textile manufacturers, fashion designers and textile machinery makers, and its pool of fashion designers. These assets have facilitated the formation of the high quality fashion industry as its core market. This choice may have led to the unintentional exclusion of the diffusion of synthetic materials – the non-desirable materials in the market - into the textile industry. Although this appears not to have a direct implication to its strategic choice, the exclusion of synthetic materials from the Italian textile industry's strategic long-term development has caused the slow development of the technical textile market. This condition may put the industry in a serious danger in the future as its core market has been in decline.

The slow diffusion of synthetic materials in to the textile industry appears to be influenced by the slow development of organic chemistry in the country. Italy was behind in research in the field compared to Germany, Britain and France, the other three major textile nations in Europe. During the development of the organic chemical industry in Europe, Italy imported special plastics for its consumption. As a result of this, the linkage between the textile manufacturers and the chemical fibre producers has never been strong. The evolution of the industry has therefore revolved around the areas where its 'stock of knowledge' was more competitive, that is, in design, quality and production flexibility. The development of the German textile industry, on the other hand, has been driven by its large stock of knowledge in chemical engineering and machine-tools manufacturing. As a result, the country leads the development in technical textiles.

Economic forces play a strategic role in driving the application of new technologies. For instance, competition in the aircraft industry, global warming and rising oil prices has encouraged demand for aircraft with greater fuel efficiency. Light-weight carbon composites found an application in the industry to replace metal sheets in certain sections of the aircraft's body. Likewise, the trend in non-invasive medical treatment opens up immense potential applications in biosensing and drug delivery.

The illustration demonstrates that the path-dependent nature of technological development, the stock of technological knowledge and economic forces encourage developments in particular directions. According to Rosenberg (1994), the greater the stock of technological knowledge possessed by a firm, the lower the cost of acquisition of some particular new technologies. In other words, the stock of technological knowledge renders acquisition of certain alternative technologies easier or cheaper.

How do firms diversify their knowledge in the areas which are distant from their productive activities? The case studies of Ten Cate and Freudenberg address this issue. At Freudenberg, its knowledge and large networks in the automotive industry encouraged the firm to start research in fuel cell technology, although it did not have the competence in the field. The firm found that its competence in the development and manufacturing of nonwovens could be developed to produce gas diffusion layers, an important component of fuel cells. In addition, its core competence in seal technology could be leveraged to produce seals for fuel cells. The latter is particularly critical to strengthen Freudenberg's position in the value chain because the technology plays a significant role in the efficiency of the assembly of fuel cells in the future. Freudenberg did not pursue other important fuel cell component technologies such as membranes and catalysts as the firm's stock of knowledge was not sufficient to add the necessary value to the market. Consequently, the cost to generate capability in the field would be higher.

The illustration demonstrates the cumulative nature of the development of technological knowledge at the firm level as argued by Rosenberg (1994). From the case studies, the path-dependent nature of knowledge development does not necessarily result in the phenomenon of lock-in. Diversification of competencies also involves some degree of path-dependent change. The firm generates new competencies through the combination of its established competencies and new technological knowledge it acquires from external sources that include its customers, partners and suppliers, as well as from collaborative research. The case studies also reveal that the decision to adopt a particular technology from a number of alternatives is not only dependent upon the stock of knowledge and economic forces. Other factors also considerably influence the firms' decision such as the cost of adoption, the perceived economic benefits, individual and organisational cognition, the availability of complementary technologies and the competitors' activities. The finding confirms and, moreover, extends Rosenberg's argument about factors that influence the path-dependent nature of technological change.

Furthermore, the case studies also suggest that the selection process to find potential markets for a new technology is also path-dependent. The firm's existing market is often selected as the initial target for a new product because of familiarity with market demand, customer behaviour and established marketing networks. In many cases the initial market is not necessarily the eventual market from which a great deal of profit is generated. Nevertheless, the initial market provides the opportunity to learn a number of aspects related to the technology and production processes, from which new applications may be found. The development of nylon as discussed earlier is an instance. In another instance, Freudenberg initially developed nonwovens to substitute leather materials which disappeared prior to the Second World War. The leather market, however, reappeared after the war. The firm started to develop nonwovens for interlinings and technical applications from which it has generated the largest profit. Rosenberg (1994) indicates that such process of market development demonstrates market uncertainties entailed in the commercialisation of new technologies.

In relation to path-dependence of organisational change, David (1994) argues that organisations and institutions are the 'carriers of history', in that the past events continuously influence the shape of the present, and that history matters to the formation of human organisations and institutions. David (1994) indicates that the phenomenon is evident in the process of change of organisational procedures that include learning, coordination, and information filtration and interpretation. Complementary procedures are gradually added into the existing system to satisfy some economic or social purposes that are important in particular period of time. The new procedures are adapted to the existing ones so that organisations *evolve* their *precedent-base rule structures incrementally*. Historical precedents are crucial in shaping the entire organisational functions and structures, simply because each of the additional components must be adapted to interlock with the pre-existing components. As a consequence of the interlocked functions, structures or procedures, changing or eliminating one established component is costly and risky because it may affect other components. Incremental change is thus preferable to minimize the risk of organisational turbulence and adjustment costs. One implication of this process is that the historical context out of which organisations are formed can become enduring constraints. Organisations are less adaptive to a rapidly changing environment which may lead to the phenomenon of lock-in. In this context, the lock-in phenomenon is caused by the failure of organisational and structural systems which renders an organisation inflexible. This study proposes a reinterpretation of lock-in to the existing structure, technology, market and routine. It is argued that lock-in attributes to the maturity-trap as a consequence of firms' inability to break down the barriers to change in a mature market.

David (1994) recognises the paradox faced by organisations. On one hand, organisations are rigid and less adaptive as a consequence of deeply-rooted complex procedures or routines. On the other hand, it is critical to overcome barriers to change in order to avoid being acquired or even ingested by competitors. This requires breaking away from the established routines, knowledge and skills to achieve *path-breaking change*. However, he does not discuss further the *process* to break the barriers to change or inertia.

The path-dependent concept is criticised by Garud and Karnoe (2001) who are concerned about the limitation of the approach to deal with deliberate efforts to create new paths or 'path creation' and escape lock-in. The concept tells us little on how new paths come into being, despite the fact that many industries such as automotive and telecommunications have shifted their technologies and development paths which have enabled them to compete in a changing competitive landscape. In the automotive industry, for instance, the development of hybrid, electric or fuel cell cars has sparked new optimism among the European car makers as the new paradigms may help them to escape from the Chinese and Indian car makers' plans to flood the market with cheap cars. Likewise, the transformation of the European textile industry from initially producing traditional cotton textiles to developing solar cell fabrics, fuel cell component technology and functional fabrics certainly requires explanation, not only from the a technical change standpoint but also from the organisational change point of view.

At the firm level, the path-dependent concept has a major flaw in that it can not explain firms' capabilities to reinvent themselves and become successful in driving new businesses forward in domains that are entirely new from their original competencies. A longitudinal study of the development of fibre glass technology by Corning is a useful example (Cattani, 2006). Cattani found that the development of fibre glass technology was as a result of the redeployment of Corning's traditional know-how in specialty glass, particularly the flame hydrolysis process to manufacture fused silica using the vapour deposition method. The production process and method was redeployed to produce glass that could satisfy the requirements of long-distance telecommunications networks. The new technology successfully replaced the dominance of copper wire in the long distant telecommunications sectors, a sector that unrelated tp Corning's traditional market.

The redeployment of existing knowledge into a new domain is referred to as technology speciation (Levinthal, 1998). This demonstrates the manner in which an established firm develops a breakthrough technology derived from the modification of its established knowledge. The breakthrough impact of the redeployment of technology is a consequence of distinct selection criteria and the degree of resources abundance in the new application domains. In the case of the application of glass fibres for the telecommunications industry, as the performance requirements in the new application was very different to those of the original application (specialty glass), Corning adopted new technologies and combined them with its glass processing capabilities. The study thereby supports the path-dependent framework in technological change, on one hand, as well as *path-breaking change,* on the other. While knowledge accumulation and adoption is path-dependent, *the application of existing knowledge into a new domain breaks the firm's development path away from its traditional path.*

This case study of Corning suggests that path-dependent change may lead to two opposite consequences. The first is the phenomenon of lock-in, and the second is the phenomenon of path-creation. The path creation refers to the circumstances whereby firms are locked-in to an inefficient structure and are trying to break out from such a structure through the modification of their existing competencies. Studies that address the process of path-breaking change at the firm level by which firms break away from the existing paths and create new competencies are crucial. This is one of the major concerns being investigated in this study.

Teece (2007) briefly addresses the issue of path-creation. He proposes the concept of 'break-out structure' by which an entirely different set of structures and procedures are established to facilitate radical change in technology, product, market and routines. It may involve transfers of non-tradable assets to and from other organisations through, among other things, mergers, acquisitions, divestments and licensing, particularly where market failure exists. A number of (quantitative) empirical studies favour acquisitions as the means to access new resources in an attempt to break out from path-dependent change (Karim and Mitchell, 2000, Vermeulen and Barkema, 2001). Access to new resources and combine them with existing capabilities can facilitate the development of new and unique competencies by which firms develop new competitive advantage, create new value proposition, overcome barriers to entry, and reduce organisational inertia. The need for acquisitions arises from the imperfect tradability of routine and resources. When substantial change is needed within a relatively short period, acquisitions are more favourable as they provide new opportunities for path-breaking changes (Karim and Mitchell, 2000). Path-breaking change results in fundamental business and organisational reconfiguration and may allow the acquirers to possess resources that are new to the firms and to the industry, although, some degree of path-dependence remains (Colpan and Hikino, 2005).

There are a number of studies that examine the factors which encourage corporate decisions in developing (internally) or buying (externally) of new competencies (see for example Narula, 2001, Vermeulen and Barkema, 2001). Compared to the external acquisitions, the internal development is believed to be more constructive to reinforce existing resources or to perform incremental changes (path-dependent changes). Narula (2001), however, argues that the underlying factors that determine the routes to source new knowledge (internal R&D, R&D alliances or outsourcing) are closely related to the development stage of the associated technologies, that is, pre-paradigmatic (before the emergence of a dominant design or ferment phase) and post-paradigmatic (after the emergence of a dominant design or mature phase), and the distribution of technological competencies of a firm. He purports that in the pre and post-paradigmatic stage, if the technology has no fundamental effects to the firm and multiple sources are available, regardless of the speed of technological development, outsourcing is the common practice. In this case, firms may decide to acquire some shares of the R&D partners as outsourcing may have an effect on the firm's confidentiality. In contrast, if the technology being developed is fundamental to the firm's major competitiveness, in-house R&D in combination with alliances with competitors (to create new standards) and suppliers (to establish a dominant design) is the most appropriate route. If the pace of technological development is taken into consideration, in addition to costs and the level of uncertainty, alliances are more favourable.

Here we agree with the arguments of Narula (2001), Karim and Mitchell (2000) and Teece (2007), that internal R&D should be combined with acquisitions of external competencies and research collaborations. The combination of these routes allows firms to continuously generate new technologies and products, and create new competencies. With regards to the maturity-trap, the new concept should be adopted by mature firms in order to bypass or break out of the maturity-trap. As suggested by Leonard-Barton (1982), core capabilities evolve, thus, corporate survival is dependent upon successfully managing that evolution.

The findings of this study make a considerable contribution to the issue above by providing new insights to the path-dependent concept pioneered David (1986) and Arthur (1989). He suggests that path dependence is related to the proposition that history matters, increasing returns and lock-in. His argument, to a great deal, supports the argument of the maturity-trap, wherein those factors reinforce short-termism, rigid production processes and inflexible organisational routines and structures. This study, however, reveals that when competing technologies exist, there are firms that want to break away from the existing paradigm driven by the desire to be different from competitors or to capitalise from emerging markets. Interestingly, the process of creation of new paths involves some degree of path-dependent change. As an illustration, in-depth knowledge in textile technology and processes may not sufficient to transform a traditional textile manufacturer to become a spacecraft manufacturer. However, the knowledge, when it is combined with knowledge in advanced materials and composite technology, may enable a textile producer to manufacture woven carbon composites for spacecraft component technologies.

2.4 Industrial De-Maturity

The conventional wisdom assumes that the decline of mature industries in developed economies is irreversible; therefore, the developed countries have to let their mature industries to fall into decline and use the resources for more competitive activities. Abernathy, et al. (1983) argue, however, that mature industries can be revived through innovations that can change the basis of competition from costs to technological competence. The argument, called industrial de-maturity, contends that *manufacturing industry can arrest maturity and even, for some circumstances, reverse the process of maturity.* The concept was developed to analyse the problem faced by the US automobile industry in the face the emergence of new low-cost competitors, that is, the Japanese automobile makers, in the 1970s. The new competitors satisfied the emerging demand which leaned towards smaller, cheaper and fuel-efficient cars with greater variety. Mass production systems employed by the US car makers which was characterised by large production volume, long production run and standardized products could not satisfy the new demand as it required production system flexibility and tighter quality control in each stage of the production process. They found themselves trapped in a large and complex supply chain developed to produce large, fuel inefficient cars with very little model variety.

Abernathy et al. (1983) suggest that the decline of the US automobile industry should have been responded to in a positive manner by encouraging more radical innovation(s) to restore its competitive advantage. This form of industrial renewal required fundamental changes in the innovation paradigm and organisational practices. In this regards, the industry should learn from its own history, particularly during its early development which has brought the industry competitive at the first place. The US car industry was built on Henry Ford's innovative efforts in product design, production and inventory systems. During the period, innovation, often radical, was performed continuously. However, as pressures in the market to reduce costs mounted, radical innovation became more incremental, the production system was standardized to improve efficiency and product variety was very low to avoid any interruption during production. To restore its competitiveness, the US car makers needed to change its outdated paradigm. Only by doing this could the industry initiate the process of de-maturity.

It shows that de-maturity can be driven by the collapse of stable relationships between customer preferences and the design concept of the technologies that fulfil the needs[2]. If the new demand is sufficiently dissimilar from the one it supersedes,

[2] Stable relationships occur in a mature industry. Such relationships are increasingly vulnerable to changes in technology, market preferences, and relative prices. Indeed, it carries intrinsic threats of

"producers may need to seek out new technology, to revise design concepts, to reintroduce innovation as an important element in competition, and to undertake new rounds of iterative learning. They may also be confronted by new technologies that make possible entirely new technical approaches to product attributes or previously unattainable levels of product performance" (Abernathy, et al., 1983, p. 27-28). Such a condition may encourage firms to move away from the prevalent innovation paradigm in a mature industry, that is, incremental innovation and initiate radical change.

There are three types of change in industrial development that may create the condition for de-maturity, that is, *new technical options, changes in customer demands* and *government policy* (Abernathy and Clark, 1985). Government policy has been the driver of the development of radical technologies or the creation of new demand. The most recent instance is the policy on climate change which has been the driver for R&D in low-carbon energy. This policy has induced new demands in clean energy for different applications. The change could provide new opportunities for long-term growth. Therefore, firms should take the necessary actions to tap into the new trends through offensive innovations that *"destroy the value of present competences, may alter the relative positions of competitors, attract new entrants and redraw an industry's competitive boundaries"* (Abernathy, at al,. 1983, p. 28). In other words, de-maturity can be initiated in the occurrence of *"innovation that changes an industry's basis of competition[3] at the same time that it disrupts established production competence, marketing and distribution systems, capital equipment, organisational structures and the skills of both managers and workers"* (p. 109).

It suggests that de-maturity corresponds to the departure from innovation characteristics, organisational structures, routines and firms' core competencies that are prevalent in the mature stage to achieve a new stage of growth. As the major driver of de-maturity is the collapse of stable relationships between customer needs and the relevant technology the transition towards de-maturity can be explained

upheaval if there is a sudden or radical shift of those aspects brought in by new competitors, technologies, demand, regulations (Abernathy, et al., 1983).

[3] The dimension of product and process among which firms seek to differentiate themselves from their competitors.

through the transition of innovation phases which are a function of its impact on productive systems and market linkages. The process of de-maturity is a transition process from incremental phase to radical phase or to architectural phase (Figure 2-2). The transition goes beyond the adoption of new technologies as a means for survival. Rather, it involves complex dynamic interactions between technology and market preferences, and entails learning processes to facilitate the creation of new competencies. Therefore, de-maturity involves not only a shift in technological innovation but also in markets and products, production systems, competencies and organisational structure and routines (Table 2-1). This process can provide new opportunities for firms to regain their technological competitive advantage.

Niche creation -the creation of market opportunities through extensive use of existing technology- may be the more favourable means for firms in a mature industry to create new sources of profit. This innovation is less risky and does not need a great deal of change in terms of technology, production systems and organisational structure and routines. De-maturity, however, has greater effects on firms' long-term growth because it allows them to achieve a competitive advantage through technological competencies, which is the characteristics of the growth path of an industry.

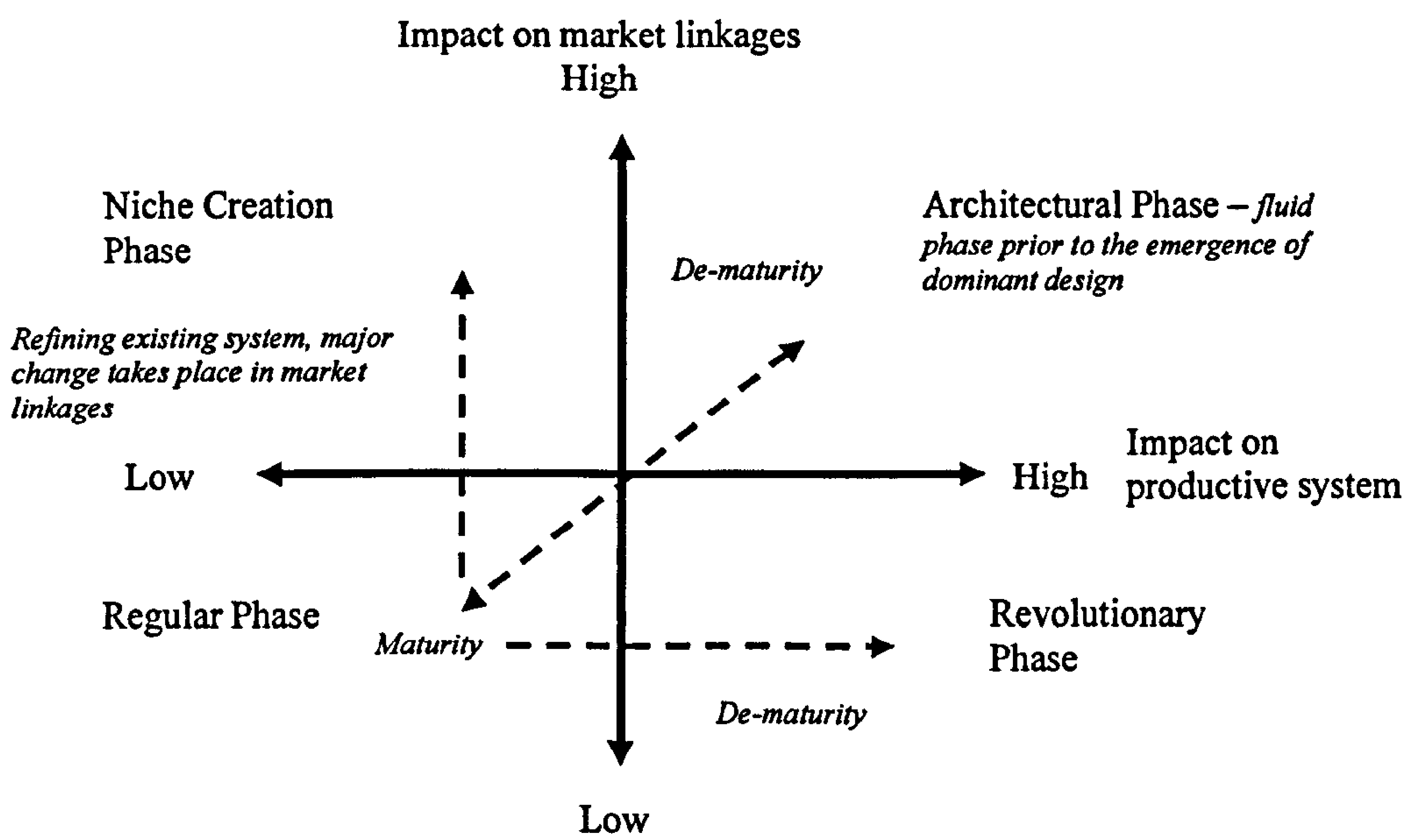

Figure 2-2. Evolution of Technology Transilience
Source: Adapted from Abernathy et al. (1983)

	Creation Phase	Mature Phase
Technological innovation	Radical or architectural innovation	Incremental Innovation
Products	Low volume, un-standardized products	High volume, standardized products
Technological phases	Technological fluid	Technological standardized
Production systems	Open-ended and unstructured system	Rigid and elaborately structured
Organisational control	Informal and entrepreneurial	Formal, emphasis on control, goals and rules

→ Transition towards maturity

← Transition towards de-maturity

Table 2-1.The characteristics of the creation and mature phase, and the direction of change (Source: adapted from Abernathy and Utterback, 1978)

As to the changed competitive environment experienced by the US automobile industry, the European textile industry's competitiveness has been severely hit by the arrival of low-cost competitors since the 1930s. A number of innovative textile firms in Europe responded to this new competition by creating and adopting new technologies that advanced their current competencies in textile production but, at the same time, destroyed their present competencies in traditional textiles to build new competencies in technical textiles. As a result, new markets, new marketing, distribution and production systems, new knowledge and new organisational structures and cultures were created and adopted. Germany and the Netherlands are two countries that had been successful in shifting their textile capabilities from traditional textile manufacturing to technical textile development earlier than other European countries. Up to now, Germany remains the largest technical textile producer in Europe. Thus, the experience of the European textile firms is very relevant to the concept of de-maturity.

At the firm level, innovative textile firms which developed new competencies in high-value-added textiles for technical applications experienced similar rigorous change in various aspects of the business. The firms experience a comprehensive transformation from traditional to technology-driven firms through a long process of transition. This became a trend in the mid 1990s as the new innovation paradigm in textiles that involved scientific advances and R&D started to attract the wider attention of the European textile community. Innovation shifted from merely adopting new textile processing technologies to improve efficiency and reduce costs to creating new high-performance textiles derived from advanced materials and improved processing technologies. Due to the high level of performance demanded by the technical textile market, textile firms initiated in-house R&D and often collaborative research with other firms. Such a shift in innovative activities or innovation paradigm, according to Abernathy at al. (1983) was an indication of de-maturity.

Such a shift was a response at the firm level to the failed protectionist regime led by the EU. Although the development rate of technical textiles has continuously increased since the 1990s following the diffusion of the technology within and across industries, the EU did not initiate a concerted effort to transform the industry until 2004 with the introduction of The European Technology Platform as mentioned in Chapter 1. Attempts to turn the EU textile industry around indicates that the topic of industrial de-maturity is still of contemporary importance. Despite the changing innovation paradigm, the industrial taxonomy maintains the classification of the textile industry within the low-tech or traditional industry (OECD, 1986) or supplier-led industry (Pavitt, 1984). Indeed, innovation studies in the textile industry remain focused on the traditional section of the industry and overlook the technical textile sector which has been the main driver of technological change and growth in the past two decades.

The innovation literature has not only overlooked innovation in the textile industry. In fact, it has overemphasised studies on R&D intensive sectors and undermined the importance of the low-and medium-technology industries (LMT) for the economy in general (Robertson, et al., 2009, von Tunzelmann and Acha, 2006, Sandven, et al., 2005). It is rather surprising as the LMT industries dominate the economies of the developed and developing economies in terms of output, capital investment or employment. In Europe, the sector represented 90 per cent of manufacturing output in 2006. The textile industry itself contributed to four percent of the EU manufacturing output. It suggests that the LMT sectors are far more dynamic and innovative than it has been widely believed. They constantly upgrade and adopt new and emerging high technologies to revolutionise their markets and renew their competencies. The sectors have experienced a transformation characterised by the use of more advanced technologies, greater variety of product offerings, market diversification and restructuring.

The discussion about the transformation process –the nature, the characteristics and the drivers- of a mature industry has been very limited (Freddi, 2009). The transformation of the German textile industry discussed in Chapter 4 shows that industrial transformation can only be achieved if the majority of firms have the capability to continuously adopt and commercialise new technologies to adapt to changing technology and demand. It suggests that industrial transformation requires the diffusion of technology not only in the textile industry but also in the user industries (such as military, medical and sports). Robertson et al. (2009) however indicate that the knowledge about the process of technological diffusion is not yet well understood. This must be addressed in innovation studies as robust knowledge in this subject will help the development of more effective technology and innovation policy to improve diffusion.

Robertson et al. (2009) further argue that central to the uncertainty about the diffusion of technology is *information flow*. They suggest that the limited flow of information from technology providers to technology users or vice versa impedes diffusion. In this respect, the government can play a role to facilitate easy and cheap access to information. Freemand and Soete (1997) however suggest that a great deal of scientific and technological knowledge is accessible. If it is true, what factors that determine the different performance of firms? In other words, in the context of this study, what factors that determine some textile firms to fall into the maturity-trap whereas others successfully bypass the trap and initiate de-maturity? Here, it has been found that, for the latter group, access to information has to be complemented with sufficient *innovative* and *entrepreneurial capabilities* of firms. These capabilities enable firms to obtain information about markets in which their competencies can be competitive and the type of information they require and its sources. Furthermore, firms should have the capability to use the information to develop competitive products and sell them in their target markets. This includes collaborative R&D programmes with suppliers and potential customers. As demand for new products and the efficacy of new technologies are often uncertain at the early stage (Rosenberg, 1996) learning process is required. This process often entails a high level of investment and a considerable time frame. As resources are limited, firms have to carefully examine and manage uncertainties. Above all, firms should possess the necessary culture to encourage continuous innovation and the ability to manage change. These two factors are particularly important as innovation on its own is not sufficient. It has to be complemented with management that can develop strategy to gain optimum benefits from innovation activities. All these factors together will help firms to bypass the danger of the maturity-trap and initiate de-maturity.

This finding accentuates the importance of the study on the process and management of innovation and diffusion of new technologies at the firm level for policy making. A rigorous understanding on the process of innovation and diffusion and on the pre-requisite capabilities which ensure growth is a critical factor for the government to develop and implement effective technology and innovation policies. The capabilities can not be built overnight. They have to be developed and tested over the course of the history of a firm. Government therefore should address the development of these capabilities in their technology and innovation policies.

De-maturity and Other Radical Technology Conceptual Frameworks

Abernathy et al. (1983) argue that the process of de-maturity involves radical innovation which disrupts the established production competence, changes the basis of competition and has an impact on the established practices. Two studies that discusses technological disruption are the disruptive technological framework (Christensen, 1997) and technological discontinuities (Tushman and Anderson, 1986). These studies examine innovations that have an impact on the disruption of the existing technologies. Both approaches explain the manner in which established technologies are displaced by breakthrough technologies introduced by new entrants. The new technology destroys the existing competencies of established firms and causes environmental uncertainty. The impact of such a disruptive technology could reach to a point where the existing technologies become obsolete and corporate and industrial leadership is reshuffled. Under such circumstances, competitors or users have to change to adapt the changing competitive environment. Those who can not change may find difficulties to compete and are forced to leave the business or are acquired by other firms.

The disruptive technology framework, while examining competence destruction, is inadequate to explain the concept of industrial de-maturity for the following reasons. The framework focuses on technologies that have disruptive impacts on the existing technologies (production competence) while the de-maturity concept looks also at changes in organisational and industrial structure and practices. De-maturity involves the *transition* of innovative characteristics from the mature phase to the revolutionary or architectural phase, over the course of industrial and organisational evolution. The disruptive technology, on the other hand, does not consider disruption in the context of organisational or industrial evolution. Rather, it places an emphasis on new entrants as the 'attacker' or the source of innovation that destabilises the existing systems. In this respect, de-maturity does not consider the origin of the attacker as a key factor that instigates de-maturity. Instead, it examines the process of industrial or organisational renewal as a deliberate attempt to change the industry's basis of competition from cost reduction to technological competence.

The disruptive technology framework suggests revolutionary and abrupt change. Levinthal (1998) and Adner and Levinthal (2002), on the other hand, studied disruptive innovations from the evolutionary process point of view. They argue that the emergence of new revolutionary technologies is not necessarily a result of breakthrough technologies. Rather, they are developed gradually derived from the existing knowledge base and being applied in new application domains –or technological speciation (Levinthal, 1998) as discussed in section 2.3. In the context of this study, the speciation argument enriches the study of de-maturity at the firm level in relation to the creation of new competencies through the combination existing and emerging knowledge to satisfy the requirements of different (maybe emerging) demand. From the level of the firm perspective, rather than destroying their established knowledge, firms modify and extend their accumulated knowledge from which they generate new sources of profit.

The case studies reveal that the process to build new competencies is indeed gradual and takes a number of years. As with Corning, the traditional textile firms had to build up R&D capabilities as the pre-requisites to build up new competencies. The capabilities were built through a combination of different routes that include hiring new qualified technical/scientific persons, acquisitions of new firms and collaboration with suppliers and customers. Continuous development of these capabilities has enabled the firms to diversify and broaden its technological capabilities and competencies. Cohen and Levinthal (1990) referred to this capacity as absorptive capacity[4]. It is found that technological speciation is only one alternative means to build new competencies that could instigate radical transformation at the firm level. Mergers and acquisitions, as well as the adoption of new radical technologies to radically change the established markets or to create new markets are two other means that could facilitate the de-maturity process.

The case studies confirm Utterback's (1994) suggestion that established firms must persistently renew and diversify their core businesses rather than simply improve and expand the established ones. Both competence improvement and diversification need to occur simultaneously. Under such circumstances, innovative firms should implement two different innovation strategies simultaneously: *i*) defensive innovation strategy to defend their existing market and/or technology trajectories through the adoption of incremental and or imitative innovations, and *ii*) offensive innovation strategy aiming for future technical and market leadership by outpacing the competitors in the introduction of new products (Freeman and Soete, 1997). The critical factor to sustain a competitive advantage over time, according to Freeman and Soete (1997), rests on firms' abilities to adapt to changing business environment through *learning processes* and *shifting innovation strategy*. For instance, the Japanese textile industry shifted its innovation strategy from imitative prior to the First World War to defensive after the Second World War and to offensive in the 1990s and beyond (Colpan and Hikino, 2005). The transition of the innovation strategy has helped the industry to remain competitive in the traditional market in the early periods of industrial development and to move in to the high-technology textile sector at a later stage.

Freeman and Soete's concept of innovation strategy confirms the de-maturity thesis from the strategy standpoint. Strategy shifts from traditional, imitative, or defensive to offensive should lead to de-maturity if the shift facilitates greater variety of product offerings, *increased competitive visibility of the technology that makes up the products* and *significant shift in the nature of innovative activity*. These

[4] Absorptive capacity is the ability of a firm to appreciate the value of new, external information, assimilate it with its existing knowledge, and apply it into commercial ends. This capacity is critical to the firm's innovative capabilities. The capability develops path-dependently in that it is a function of the firm's prior related knowledge (Cohen and Levinthal, 1990).

have to be achieved through the destruction and replacement of the existing production competencies and its linkages with market preferences. There must be *a major increase in the diversity of technology* to meet the shift in consumer preferences. If only *a few technical alternatives* emerge, the change could be incremental in nature (Abernathy, et al., 1983).

The implication of this concept is that firms have to constantly have access to the necessary information which helps them to make strategic decisions about what and how to change or to develop new competencies. The creation of and a shift to new competencies entails a certain level of risk. The gaps between the existing and new capabilities, assets, know-how and strategy need to be filled and the process of change needs to be managed properly (Figure 2-3). Firms, constrained by their resources, capabilities and bounded rationality on one hand, and technology and market uncertainties, on the other, find it very challenging to make decisions. The balance between opportunities and risks should be maintained. Excessive aversion to risk may cause firms to fall into the maturity-trap whereas the opposite may lead to bankruptcy. In addition, firms need to decide the appropriate timing for change which adds to the complexity of the decision making process. This requires a number of factors to be considered that include the firm's perception about the readiness of the market; the maturity of the products/technologies, competitors' responses and the availability of complementary technologies. As de-maturity entails a shift from process innovation to product innovation (Figure 2-4), with regards to the shift of innovation strategy, the cost of transition from one strategy to another is also an important determining factor.

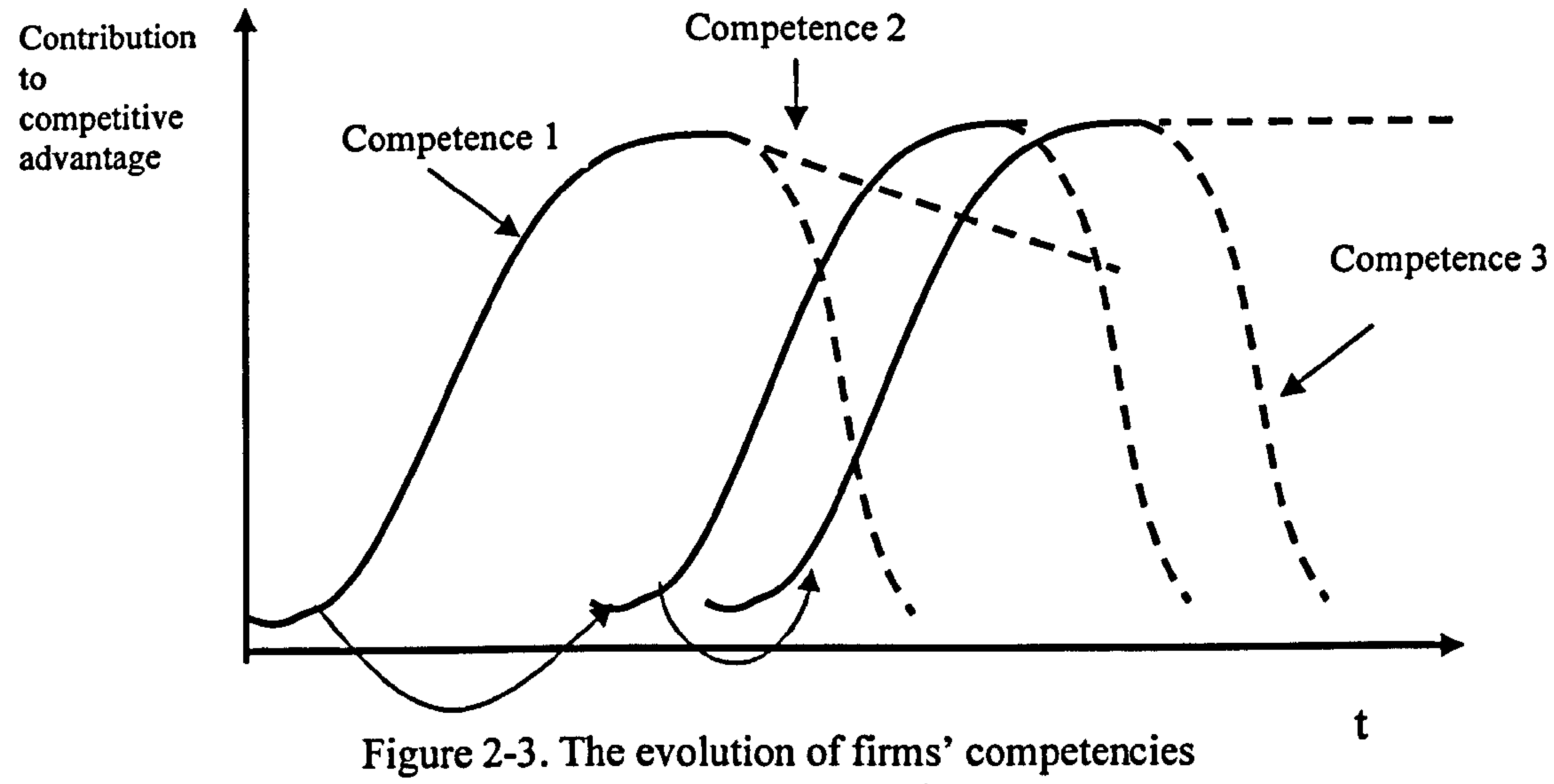

Figure 2-3. The evolution of firms' competencies
Source: Author

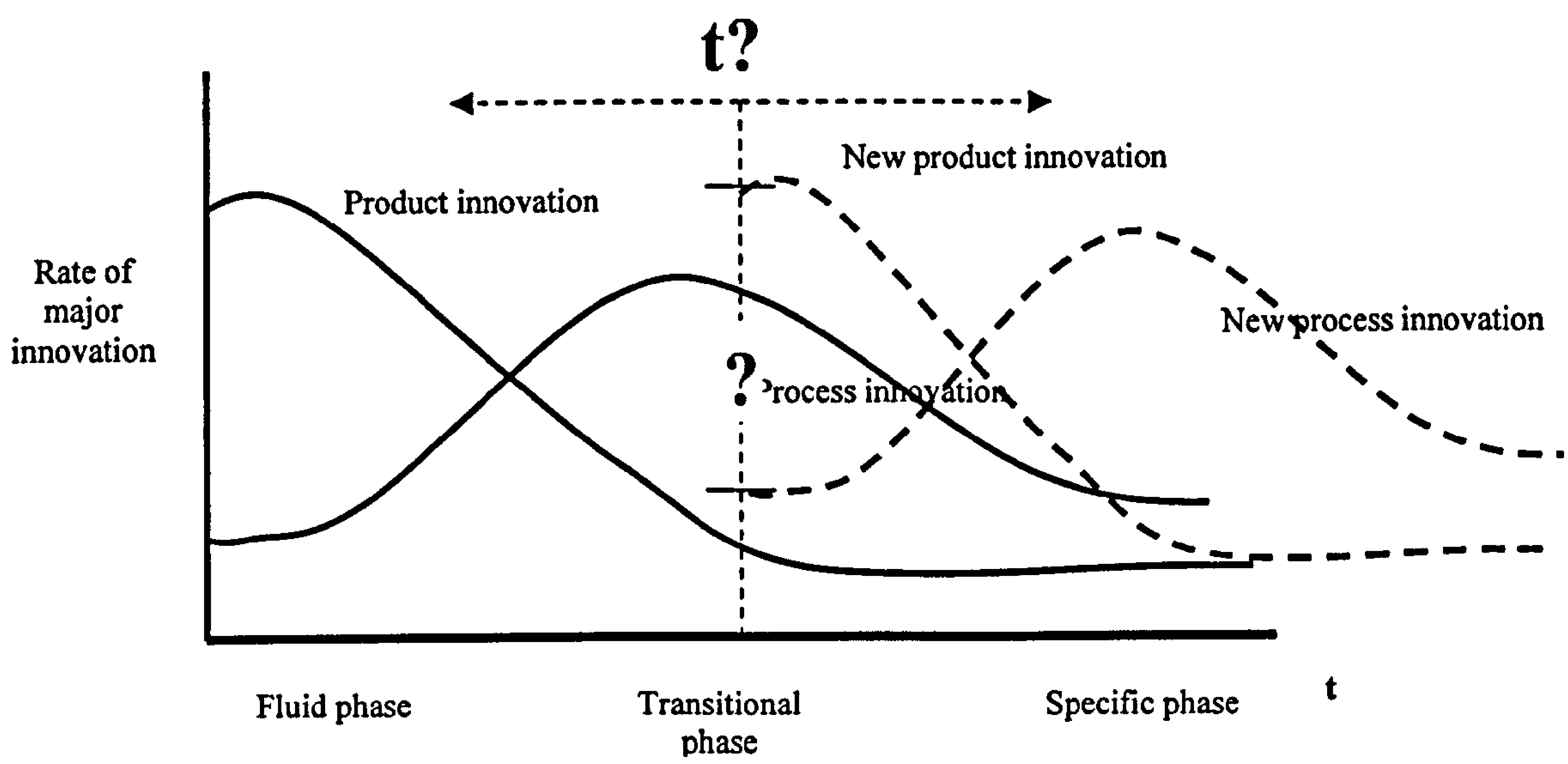

Figure 2-4. The dynamics of innovation – the shift from process to product innovation during the transition towards de-maturity
Source: Adapted from Utterback (1994) p. xvii

It is shown in Chapter 4 that technological change in the EU textile industry has leveraged the industry's knowledge-base to include advanced materials, plastic electronics, telecommunications technology and nanotechnology. The application of these technologies in textiles has the potential to create a myriad of applications of textile products, ranging from water-repellent textiles, solar cell fabrics and armour composite to GPRS embedded ski outfits and biosensing jackets. Meanwhile, the traditional fibre and textile technology, that is, spinning, weaving, printing and finishing, have also evolved to facilitate the production of new high-value added textile products. For example, melt-spinning technology can now produce fibres at the micro-metre scale and electrospinning can produce fibres at the nano-metre scale. Fibres at this dimension can be used to develop a wide range of technical textiles such as body armour and scaffolds for tissue engineering. The development of weaving technology has been directed towards *i)* flexible equipment to enable the production of different forms of weaving; and *ii)* new construction of woven fabrics such as 3D weaving. In the meantime, nonwoven textile technology has eliminated the need for weaving process to produce a wide range of textile products for various applications that include filtration, floorcoverings and apparel at very low costs. Research to eliminate the weaving process to produce clothing is also underway. One fascinating development is the capability to print functional nanomaterials on fabrics. This technology makes possible the creation of numerous functional fabrics for various purposes that include clothing (water and stain-proof fabrics), medical purposes (drug delivery), power generation (solar-cell fabrics) and security tags.

The development of these technologies may replace the traditional textile technology for the technical textile market in the future. It is therefore plausible to argue that the EU textile industry is on the verge of a new process of de-maturity. Whether or not the technology will diffuse into the traditional sector it remains to be seen. Nevertheless, a number of new developments in clothing textile markets show the possibilities of these technologies of being adopted by the traditional sector.

In brief, the study of de-maturity of an industry is about investigating the transition from the regular phase to revolutionary or architectural phase. Abernathy and Clark (1985) suggest that it is at the point of transition that originating firms which can not compete in the new environment are forced to make an exit. They are replaced by new firms better able to manage in the new mode of competition. Therefore, it is especially important to investigate further the nature of transitions and the determinants of survival within the dynamic context of the firm, technology, market and competition. This is indeed one of the objectives of this study. For the European textile industry, in particular, the success of the new Textile Technology Platform to transform the industry into a technology-driven industry is dependent upon managing the transition. This includes the capability of the majority of the EU textile firms to adopt, develop and commercialise the new technologies. Their success is also dependent on the capability of those firms to read the trends and find new applications that satisfy potential customers' latent needs.

2.5 The Open Innovation Paradigm

Central to this study is examining the transition of the European textile industry, from a traditional to a high-technology industry. One fundamental difference between the two industrial paradigms, according to the taxonomy by Pavitt (1984), lies upon the patterns of innovative activities. As discussed earlier, Abernathy *et al.* (1983) suggest that a shift in innovative activities is one of a few signs of industrial de-maturity. However, Abernathy *et al.* (1983) do not explain further the strategy and process to enable de-maturity.

The Open Innovation (OI) paradigm by Chesbrough (2006) is highly appropriate to analyse issues related to the changing innovation paradigm. The framework encompasses the technological and non-technological aspects of an organisation that facilitate change. The framework focuses on the changing innovation paradigm in the high technology sector. The framework is appropriate for this study as the European textile industry is in the process of paradigm change from being a supplier-led (Pavitt, 1984) to the open innovation paradigm. Therefore, examining a shift in the innovation paradigm in textile firms can provide an explanation of the transition of firms in a mature industry in which the framework lacks.

Chesbrough (2006) shows that a number of high-technology firms such as IBM, Intel and Lucent Technologies have moved to OI, a new paradigm he argued to have become the new imperative that should be adopted by technology and non-technology based firms. The OI is:

> *"a paradigm that assumes that firms can and should use external as well as internal ideas, and internal and external paths to market, as the firms look to advance their technology. It combines internal and external ideas into architectures and systems whose requirements are defined by a business model. The business model utilizes both external and internal ideas to create value while defining internal mechanism to claim some portion of that value. The Open Innovation assumes that internal ideas can also be taken to market through*

external channels outside the current business of the firm, to generate additional value" (Chesbrough, 2006 p. xxiv).

He explains the old R&D paradigm, –Closed Innovation[5]- that brought success to a number of prominent high-technology firms such as Xerox and IBM in the 20th century is no longer suitable for the competitive environment in the 21st century. This is because of the abundant knowledge landscape and ever rising R&D costs which have made control over technological knowledge by a few large firms difficult to achieve. Valuable ideas can come from any number of sources and it is impossible for any single firm to manage. He suggests that increasing technological competition due to the increased mobility of highly experienced and skilled people, easier and cheaper access to knowledge discovered elsewhere, and growing recognition to the role of venture capital to nurture specialised new firms or start-ups have eroded the effectiveness of closed innovation. Under such circumstances, firms are encouraged to reduce time to market for products and services -hence shorter technology life time-, and to develop multi-technology products, as the means to provide competitive solutions. Firms need to work together with other firms - suppliers, customers and competitors- or to license externally-generated technologies. The underlying argument is that relying entirely on a firm's own ideas and resources or competencies no longer adequate to provide a significant competitive advantage. These conditions have forced a number of high-technology firms to make a fundamental shift away from the old paradigm. The shift involves changing their mind-set from ideas-abound internal industrial research and vertical integration to an entirely new innovation paradigm which includes the acquisition of external developments, collaboration of R&D and marketing, and structural decentralisation.

Likewise, firms also need to radically revise their approach in terms of commercialisation of innovation. Firms can longer restrict their commercialisation practice to a single path to market. Chesbrough (2006) indicates that failure in commercialisation among high-technology firms is, in greater deal, affected by market uncertainty than by technical uncertainty. Xerox's failure was mainly due to

[5] Closed Innovation is a paradigm that solely relies on internal competencies and capabilities in the process of innovation from idea generation to commercialisation. This paradigm encouraged firms to establish a central research laboratory in the early 20th century (Chesbrough, 2006).

its falure to commercialise a number of its valuable research results rather than to master the technology. The firm was unable to break away from its traditional approach to commercialising technologies. It lacked a systemic process for exploring and evaluating alternative business models. For instance, 3COM and Adobe were spun-off from Xerox's PARC Lab as Xerox could not realise the potential economic value of the technologies. Xerox's problem was it applied the same business model it used for its traditional business, the copier and printer businesses, to emerging technologies. This led Xerox to lose its investment in these new technologies. The two technologies were successfully commercialised after the respective inventors devised new business models.

The application of OI is dependent upon each firm's priorities and its perception of the competitive landscape in their relevant industries. Chesbrough (2006) has uncovered three approaches to manage innovation generated from the principles of OI. The first concerns the internal research commitment to developing a different business model for leveraging its technology. IBM shifted its innovation approach from internally-dependent sources of innovation (or academic research) to include customers as the primary source of innovation. The firm expanded its customer base and used different business models to deliver values for different customers within its value chain. IBM adopted the internet, an externally-invented technology, to leverage its business and to provide a range of different solutions for different customers. The second approach connects internal and external research with corporate venture capital to grow a business model. Intel does little fundamental research on its own. Instead, it seeks potential new developments performed by other organisations and uses its corporate venture capital, Intel Capital, to acquire the new technologies. The external technologies are complemented by Intel's internally-developed technologies in order to provide competitive solutions for their customers and to offer a range of technologies for different markets. The third approach is related to the formation of new firms to commercialise and continue the development of new technologies initially developed internally. This approach has to be complemented with the invention of new business models to commercialise the new technologies. This is an alternative to that used by Intel. In addition to licensing its technologies Lucent Technologies established New Venture Groups (NVG) which functions as an internal business development unit, as well as a source of the fruits of its internal research. Lucent Technologies argued that this approach permitted the creation of new commercialisation paths and facilitated faster time to market. The new business development activities in Lucent were balanced with innovations that support the firm's existing business.

Chesbrough (2006), however, suggests that each approach entailed inherent risks. When the technology bubble burst in 2000-2001, Lucent's NGV was sold to a group of external investors led by Coller Capital. Although the unit had created more than $200 M in value (or about €133 M) by 2001, the firm could not convert the value of the corporate's new technology venture portfolio into shareholders value, due to a lack of appropriate metrics to measure the value on the market. Lucent obtained $100 M in cash for its share in NGV but it lost the infrastructure that connected the laboratories and business units. Meanwhile, Intel's strength in extensive uses of external knowledge potentially limits its success in the future. The trend in the semiconductor industry appears to lean towards the domain of quantum computing, a domain that might bring about a revolutionary breakthrough in semiconducting technology. Intel has to acquire knowledge in this domain if the firm is to prevent other competitors from catching up. However, to enable the integration of knowledge in quantum computing into its own systems, a huge amount of internal research is required to transfer the knowledge into the production stage. This is the kind of research Intel has not historically performed.

Our studies suggest that firms that adopt OI in the process of de-maturity acquire external knowledge and know-how to help them to break away from their established knowledge and development paths. Freudenberg, in particular, has adopted a combination of Intel's and Lucent's approaches. However, unlike Lucent or Intel's individual approaches that place an emphasis on external (Intel) or internal (Lucent) developments, Freudenberg (as well as Ten Cate) combine their internal R&D with collaborative R&D and alliances in order to keep abreast of scientific and technological advances. They also use other means, including acquisitions, licensing (in and out) and joint ventures. The decision to externally acquire or to internally develop a new technology depends upon the routines that enable the firms to foresee the future, upon the competences they posses and upon the availability and the cost of the complementary knowledge they need. To avoid becoming a conglomerate, they select opportunities that have strategic relevance to their core technologies and businesses. Similar to Intel, Freudenberg and Ten Cate do not perform fundamental research. Rather, they acquire new knowledge through research collaborations with universities and public research institutions. With regards to technology commercialisation, in addition to licensing, they conduct internal and external venturing either through a dedicated organisation (Freudenberg New Technologies, under which a corporate venture capital and a new business development unit are managed) or through relevant business units (Ten Cate).

Chesbrough suggests that firms need an 'architecture' to help them to integrate internal and external technologies. Our case studies suggest that the architecture should include dynamic capabilities (Teece, et *al.*, 1997), a framework that is discussed in the next section. Dynamic capabilities enable firms to create, deploy and protect intangible assets that support superior long-run business performance. The development of dynamic capabilities requires certain skills, knowledge, facilities, organisational structures, rules and culture. Moreover, flexibility to change or modify those elements to suit the new business environment is vital to enable organisational transformation. For example, when IBM embraced the OI it expanded the role of researchers from being solely knowledge generators into being knowledge brokers. Meanwhile, Lucent established a communications infrastructure between its researchers and business development people in NVG which facilitated the diffusion of knowledge between the two parties.

Teece (2007) suggests that enterprises with strong dynamic capabilities are intensely entrepreneurial, because they not only have to adapt to the business environment but are more proactive through innovation and collaboration. An entrepreneurial-based capability allows a firm to develop 'sensing, seizing and reconfiguring' capacities that are difficult to develop and deploy, or, in other words, unique and difficult to imitate assets. This capability is driven by entrepreneurial management who have the capacity to recognise opportunities and seize them through the strategic deployment of resources. Our case studies (and the example of IBM), also demonstrate the need for leaders with a new vision, a broad perspective towards the needs of a firm, and an entrepreneurial capability to turn the firm around and put it in a new direction (example of Xerox and IBM in Chesbrough, 2006).

2.6 The Dynamic Capabilities Framework

It has been discussed earlier that the European textile industry is undergoing a transition phase, moving away from being a traditional industry to a technology-driven industry. The transformation process is gradual, as a consequence of the path-dependent nature of technological change and organisational evolution. However, the consequence of such activities to organisational capabilities has not been discussed.

Indeed, Abernathy, *et al.* (1983) and Abernathy and Clark (1985) indicate that the implications of de-maturity on organisational and managerial capabilities, particularly during the transition is crucial. In fact, Grandstrand *et al.* (1997) and Chesbrough (2006) argue that it is *organisational capability,* rather than technological superiority, that enables a firm to swiftly respond to a changing business environment. Grandstrand *et al.* suggest that failure to exploit radically new technologies is a consequence of failure in *product development, production, marketing and organisational adaptation* than in technological competencies. Meanwhile, Chesbrough indicates that in the face of new competitors or changing market demand, a number of large firms found themselves in severe difficulties, not because of lacking technological competencies but because of inflexible organisational or managerial capabilities. In this respect, the case studies here reveal that organisational and entrepreneurial capabilities are indeed two of the key determinants of corporate survival.

The appropriate framework to analyse this issue is the dynamic capabilities framework (Teece and Pisano, 1994, Teece *et al.*, 1997, Teece, 2007). Dynamic capability is defined as the firm's organisational ability to build, integrate and reconfigure internal and external assets to address a rapidly changing environment. The framework is built upon the theoretical foundations of Schumpeter (1934), Penrose (1959), Williamson (1975, 1985), Barney (1986), Nelson and Winter (1982), and Teece (1988) to analyse the *sources* and *methods* of wealth creation captured by private firms operating in an environment of rapid technological change. The literature attempts to unearth the *foundation of long-run enterprise success* with an emphasis on the key role of strategic management in adapting, integrating and reconfiguring internal and external organisational skills, resources and functional competencies.

Teece (2007) suggests that the foundation of enterprise success today depends very little on cost-reduction. It is necessary but insufficient to sustain a firm's competitive advantage in the long-run. Rather, firms should depend on (among other things) new discoveries, organisational flexibility and efficient and effective technology transfer processes to adapt to a rapidly changing business environment, including the invention of new business models. It also involves shaping new rules of the game in the global marketplace. The challenge would be to find *strong-willed executives* who have the capabilities to make sensible judgments about the future, develop competitive business models and strategies and strategically pull the necessary resources to achieve the desired outcome. Firms have to establish a proper *corporate innovative culture* that facilitates creativity and innovativeness. Furthermore, they have to create the necessary *organisational structure and routines* that permits coordination and integration, and yet allows diverse projects to run concurrently to support the short, medium and long-term objectives.

Dynamic capabilities are the foundation stone for continuous change and the underlying factors of a long-term competitive advantage (Teece and Pisano, 1994). They are *organisational capabilities required to manage a firm's internal processes or routines, create or acquire unique and difficult-to-replicate/imitate assets, and examine the path the firm has travelled and envision the potential future alternative paths* (Teece, *et al.*, 1997). In other words, dynamic capability is an organisation's ability to orchestrate internal technological, organisational and managerial processes, all of which are shaped by the firms' *specific* (non-purchasable) assets positions and moulded by its evolutionary and co-evolutionary paths (Teece, *et al.*, 1997). A firm's *asset positions* determine its competitive advantage at any point in time, its *evolutionary path* constrains the types of industrial activities in which a firm can be competitive while its *organisational processes* gradually transform the capabilities of the firm. In this regards, the framework demonstrates its linkage with the path-dependent aspect of technological change (Rosenberg, 1994) and organisational evolution (David, 1994).

The dynamic capabilities framework complements the argument of de-maturity in that it provides the conceptual framework to analyse the necessary organisational processes and capabilities to facilitate internal creative destruction to achieve a sustainable competitive advantage. The dynamic capabilities framework and the maturity/de-maturity thesis share the same argument that competitiveness does not exclusively depend on technical novelty. Equally important are the organisational and management aspects of a business, particularly when changes in the competitive landscape occur either as a result of new technology, a shift in market preferences or new competition.

A number of elements that are attributable to distinctive dynamic capabilities have been identified; they are difficult-to-imitate collection of *i)* performance routines operating inside the firms, such as new product and process development routines, viable business model design and implementation routines; *ii)* skills and knowledge assets; and *iii)* complementary assets, which include reputation, brands and business networks. A large number of organisational routines such as learning processes, coordination of internal and external processes and incentive systems, are firm-specific and contextual-dependent (Nelson and Winter, 1982). The coherence of routines, which consists of a number of routines being connected to and complemented with each other, are built over a period of time, often over the entire course of the firm's history. Thus, these routines are unique and the replication of those routines from one economic setting to another is simply impossible.

In addition to being unique, these routines are often deeply engrained and solidified within an organisation. The firm's core capabilities, however, may turn into core rigidities in the case of a changing business environment (Leonard-Barton, 1992) as routines that work well in one context or period may not be applicable in different contexts or periods, even within the same organisation. Therefore, having unique, superior core capabilities is not necessarily adequate if the firm does not possess the capabilities to change them to fit with the new environment. In other words, the firm is trapped in its 'static capabilities'.

An organisation has to have a certain capacity to learn that enables it to recognise, learn, adopt, and create new activities and routines so that current competencies can be improved or disposed of and new ones can be created. It is called strategic fit or evolutionary fit (Teece, 2007). Such a learning capacity improves the organisation's absorptive capacity, a critical element of dynamic capabilities (Zahra and George, 2002). Dynamic capabilities facilitate optimization of absorptive capacity through commitments to resource deployment, appropriate organisational structure, and necessary routines. Dynamic capabilities that foster change and transformation are crucial in the creation of adaptive organisations. Changing routines, however, involves complex processes and coordination, and is costly. Therefore, routine-based dynamic capabilities have to be complemented by *entrepreneurial leadership and management* that are able to select new opportunities and seize them, and to swiftly build, integrate, combine, protect, and reconfigure tangible and intangible assets at justifiable costs. Thus, in addition to routine-based dynamic capabilities, capabilities that are built on entrepreneurial actions are equally important (Teece, 2007).

Discussion on dynamic capabilities in the innovation literature has developed further with issues around the use of the concept in firm's innovation strategy, processes and management. A particular emphasis has been to identify relevant variables and their interrelationships (see for example Eisenhardt and Martin, 2000, Helfat, *et al.*, 2007). Eisenhardt and Martin (2002) examined the influence of market dynamics, from moderate to high-velocity change, to the effective patterns of dynamic capabilities. They argue that in a moderately dynamic (mature) market, the effective dynamic capabilities emphasise incremental improvement and variety creation through the exploitation of the cumulative existing knowledge and processes (routines). In contrast, in the high-velocity market, dynamic capabilities rely on rapid creation of situation-specific new knowledge, as competitive advantage was often short-term. Hence, the creation of a series of temporary advantages faster than the competitors was the key, while the strategic logic was opportunities and selection of direction. Helfat *et al.* (2007) argue that capabilities follow a lifecycle or evolutionary path. The capabilities could be transformed/altered to a different trajectory in any stage of its evolutionary path as a response to selection events - threats or opportunities, internal or external to the organisations. Capability transformation may occur in the form of retirement (death), retrenchment, replication, renewal, redeployment and recombination. Retrenchment and replication were attributable to maintaining the capabilities, whereas renewal, redeployment and recombination led to the transformation or the creation of new capabilities.

The studies discussed above illustrate the different aspects of dynamic capabilities. Their arguments, nevertheless, converge on the fundamental elements of dynamic capabilities proposed by Teece *et al.* (1997) and Teece (2007): *i)* capability is based on organisational process ('routine'); *ii)* learning process is a fundamental factor in building dynamic capabilities; *iii)* dynamic capabilities are path-dependent, *iv)* different routines are required to maintain and refocus capabilities in moderately-changing environment and to create them in fast-changing environment.

In addition, Augier and Teece (2006) and Teece (2007) add a fundamental argument that, in addition to routine-based capabilities, *entrepreneurial* abilities are crucial to enable a firm to *shape* the environment. This argument corresponds with that of Lazonick and Prencipe (2005) as entrepreneurial ability is commonly associated with personal talent. This study suggests that management's entrepreneurial and leadership abilities are indeed central to the orchestration of capacity development to develop dynamic capabilities and sustainable competitiveness. In particular, the case studies suggest that such abilities enable firms *to sense when to change, to understand what to learn, where to learn and how to implement, and to comprehend where and how to change*. Different 'forms' of entrepreneurial and leadership abilities are required under different conditions. These findings confirm the concept of 'evolutionary fitness' proposed by Helfat *et al.* (2007).

One striking difference among the studies was made by Eisenhardt and Martin (2000) in which the non-imitability, non-replicability and non-substitutability aspects of dynamic capabilities are challenged. They argue that dynamic capabilities exhibit common features across firms which are frequently referred to as 'best practices'. The commonalities emerge because organisations are often able to perceive effective patterns in dealing with different organisational, interpersonal, and mechanical challenges that must be addressed by a given capability; hence, the emergence of, for instance, new product development routine, strategic decision making routine; and knowledge creation routine. The commonalities of key attributes of particular dynamic capabilities rendered *equifinality*.

This argument is challenged by Augier and Teece (2006) and Teece (2007) who argue that implementing widely adopted best practices could not by themselves enable firms to gain long-term competitiveness because of the dynamics of market, technology, and competition. Furthermore, equifinality is rarely, if not impossible, to obtain as different paths taken by different firms, even to achieve the same objective, may lead to different end points. The differences in history, human capital, social capital and cognition of team members may determine the eventualities (Helfat and Peteraf, 2003).

The case studies here confirm the arguments made by Helfat and Peteraf, and Teece. The capability of individual firms to direct change, create competitive strategy for change and manage the transitions, technologically and organisationally, will determine the outcome. It is found that the perception of the management about the future market significantly affects the paths taken by individual firms. In addition, their decisions were based on the stock of knowledge, the cost of acquiring new knowledge, competitors' strategies and the availability of complementary knowledge or technology. These are (among) the underlying factors of firm heterogeneity.

2.7 Conclusion

This literature review covers a wide range of literature to understand the transition of the European textile industry, from a mature to a technology-driven industry form the standpoint of the level of the firm. To conclude, the de-maturity framework shows that reversed industrial evolution, from mature to ferment (or creation) phase, is possible. Such a fundamental transformation will take considerable time as the industry is predominantly populated by a large number of firms with limited capabilities. Through these frameworks, it is now possible to explain a number of necessary issues that will contribute to such a transformation. The maturity-trap appears to impede the process of innovation that allows the transformation because of different aspects of inertia, including organisation and cognition. The path-dependent nature of technological change and organisational development is also attributable to the slow and gradual process of transformation and the possibility of falling into the maturity-trap. Having said that, it is argued path-dependence does not automatically lead to lock-in. Firms which have successfully initiated the process of de-maturity instigated path-breaking change to move away from their traditional paths. In this regard, the dynamic capabilities framework provides us with an analytical framework to address the issue. Evolutionary fit, which corresponds with the continuous creation of new competencies to adapt to or to shape the competitive landscape, will facilitate a sustainable competitive advantage. This is indeed the strategic implication of de-maturity.

The next chapter discusses the phenomenon of the maturity-trap through the experience of the Lancashire cotton industry and Courtaulds. The Lancashire cotton industry and Courtaulds were once iconic in their fields, dominating the global market during their heyday. The industry and the firm however fell into the maturity-trap as they were unable (or unwilling) to change in the face of a changing competitive environment. The discussion explains the argument of the maturity-trap from the perspective of the industry and firm level. This provides important insights about our understanding on the maturity-trap and the relevance of the concept to the current situation of the EU textile industry.

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3

The Decline of the Lancashire Cotton Industry: An Early Case of the 'Maturity-Trap'?

3.1 Introduction

In the 19th century, the Lancashire cotton industry dominated the global textile trade. During its peak in the 1880s, 80 per cent of the cotton export market was supplied by the British industry which employed 600 000 workers in spinning, doubling and weaving, in addition to 100 000 in finishing (Owen, 1999, Lazonick, 1983). Its size led the industry to become the largest employer in the country. The industry's contribution to British economy was highly significant, representing approximately 50 per cent of the country's export (in terms of value) between 1835-1840.

Since the interwar years, the industry has gradually lost ground to competitors from low-cost countries which offered significantly lower priced products. Its share of the global export market fell to 30 per cent in 1937, after which the figure continued to decline. A number of attempts at restructuring through capacity reduction (from 1939) and modernisation (from 1948) failed to restore the competitiveness of the industry. Instead, the industry's competitive position continued to weaken not only in relation to low-cost competitors but also to other high wage economies in Europe, particularly Germany and Italy, from the 1970s onwards (Rose, 1991, Toyne, *et al.*, 1984). Given its domination in the global textile trade and its contribution to the British economy for over a century, the relative decline of the British cotton industry represents one of major examples of economic decline in the history of industrial capitalism (Lazonick, 1983).

Why did a powerful, advanced industrial nation fall victim in the face of growing competition from lower-cost countries? The debate over the alleged causes of the decline has been a most hotly contested issue. It is argued here that the causes identified by Singleton and Lazonick lean towards the phenomenon of the maturity-trap". The firms continued to function based on *economic individualism*[1] and a once highly competitive *craft-based production system* which grew during the 19th century although the practice was no longer fit for purpose in the new competitive environment of the 20th century. The British textile industry found it difficult to respond to the modern corporate system of the Japanese and American industries, the leaders in the early 20th century, characterised by centralised control, integrated business systems and mass production. Ironically, the factors which impeded change were the traditions on which Britain's hegemony was built.

What is quite alarming is the maturity-trap appears to persist. In the 1970s the British textile industry once again failed to adapt to a changing business environment pioneered by the Italian textile industry. In more recent years, the European textile industry appeared to experience yet another shakeout affected by the emergence of China as the new dominant power in the global textile market. Furthermore, market saturation of once high-value added products developed in the 1960s-1980s and the recent shift of demand towards more affordable products have added to the complexity of problems faced by the EU textile industry. Although it is clearly apparent that external conditions change continuously, the EU textile industry remains dependent on the traditional textile market, that is, clothing and household products, which have been under increased pressure from low-cost countries.

The emergence of China should not be underestimated. Although the domination of the country is concentrated on the low-end market up to now it is not impossible that it can improve its textile capabilities and produce higher-value added textile products to catch-up with the quality of European firms. In fact, a number of Chinese firms have received orders from leading luxury brands and high technology

[1] This is a doctrine which provides priority for individuals in their decisions in economic activities, before government or community, for them. This doctrine often impedes collective actions as the government cannot impose regulations without receiving agreements from individuals.

textile producers in Europe and USA. However, the practice is protected under a non-disclosure agreement as any publicity would damage the reputation of the brands (Economist, 2009). In another instance, the acquisition of IBM's computer business by Lenovo (China) and Jaguar by Tata Motors (India) shows how industries in developing countries can rapidly move up the value chain and build up a reputation in high quality products whilst maintaining lower costs.

This chapter examines the phenomenon of the maturity-trap through the analysis of the relevant factors, the process which leads to the trap and its effects. The experience of the Lancashire cotton industry is used as the initial starting point on how the industry fell into the maturity-trap. The Lancashire textile industry has strong parallels with the European textile industry as it appears that the maturity-trap has an extremely longevity. The lessons from past experience need be examined carefully to help the EU textile industry to escape from the maturity-trap in the future. The European textile industry cannot afford to overlook the threats posed by recent developments and fall into the maturity-trap. The conclusion will be used to support the analysis of the case studies in Chapters 5-7.

3.2 The Lancashire Cotton Industry

The Lancashire cotton industry experienced tremendous growth between 19th century and the first decade of the 20th century. During the period, a large number of new firms entered the industry and capacity increased considerably. In 1930 there were more than 2000 cotton yarn and cloth producers in Britain and the capacity reached 8000 million yards of cloth (Lazonick, 1983). The country represented 40 per cent of world's capacity and controlled 60 per cent of the world cotton goods markets (Tippett, 1969). Its market spanned Europe, Asia and South and North America (excluding USA). The market for fine yarns and cloths in Europe however had declined considerably since 1879 because of tariff walls and the ability of individual countries to fulfil their own markets. Britain thus shifted its major market to coarser products from 1870. The country dominated the import of cotton products in India and China between 1889-1913. India was, by a considerable extent, its largest overseas market and constituted 46 per cent of its exports, followed by China, Japan, and Central and South America. The industry's share of the domestic market was only 12 per cent of production.

The growth of the industry had a concomitant effect on its structure. The considerable size of overseas markets encouraged new players to enter the market. As the investment required in a specialised function (spinning, weaving or finishing) was considerably less than in a combined function (spinning and weaving or spinning, weaving and finishing), the new entrants, the majority of which were small and medium-sized firms, increased the population of specialised firms, These firms had become increasingly dominant in the industry from the 1850s. In the period of absolute growth, specialisation permitted capacity expansion to supply the growing demand as the barriers to entry were relatively low. As a result of this, the structure of the industry changed from being vertically integrated to horizontally specialised.

Specialisation also encouraged geographical concentration within a few industrial districts. The spinning industry became increasingly localised in the south of Lancashire such as Oldham for coarser-yarns and Bolton for finer yarns. The weaving industry was concentrated in the northwest region of Lancashire such as Burnley for coarser cloths and Nelson and Colne for finer cloths. Both industries were linked by the Liverpool and Manchester Exchange at which the yarn and cloth trade took place (Lazonick, 1983).

Specialisation and *geographical concentration* were the distinct features of the Lancashire cotton industry on which its superiority was built. The structure was highly efficient and productive. Skills were accumulated within each industrial district thus helping the transfer of knowledge from one generation to the next. Other complementary clusters such as machine builders, skilled mechanics and other service providers also emerged to specially serve the needs of the local industry. Mill owners did not need to look for services outside their districts, contributing to the efficiency of the system. The proximity of the machine suppliers and other service providers allowed the spinners, weavers or finishers to learn from each other. The close relationship helped not only the efficiency of the manufacturers but also the development of new machines.

Specialisation within industrial districts allowed the cost of logistics and transportation (such as for purchasing and shipping cotton) to be divided among firms within the Lancashire area. As a result of this, employers who set up factories within Lancashire districts possessed distinct competitive advantages over those who did not, owing to the accessibility of the necessary infrastructure and skilled people. These factors attracted a great deal of new entrants, new investment and new buyers, and reinforced the specialisation and geographical concentration (Owen, 1999, Mass and Lazonick, 1990).

Britain's dominance of the global textile trade began to decline in the early 1920s in the face of new competition from low-cost countries. Production and exports fell significantly as former overseas markets developed themselves by which they met their own demand and, furthermore, competed with Britain in foreign markets. India, Hong Kong and Pakistan emerged as the major textile suppliers both for their own markets as well as for the British market. The latter was facilitated by the agreement between Britain and Commonwealth countries that allowed products to be imported duty free under the Imperial Preference scheme[2]. It was Japan, however, which posed a more serious threat to Britain's domination. Within 30 years of its industrialisation programme, Japan transformed itself from a textile importing country to become a major global exporter, seizing the market which belonged to Britain, the world's oldest and largest textile producing country. In India, Britain's share in the imported cloth market declined from 97 per cent to 50 per cent between 1914-1932, whereas the Japanese firms enjoyed an increase from 0.1 per cent to 45 per cent. In a similar fashion, Britain's share of China's cotton import market was 13 per cent in 1930, down from 53 per cent in 1913, whereas Japan's share leapt to 72 per cent from only 20 per cent during the same period. The government attempted to halt the decline with the imposition of tariffs and quotas on Japanese imports in colonial markets after 1934 (Owen, 1999, Dupree, 1996).

The competitiveness of the Lancashire cotton industry continued to decline in overseas markets as the individual countries introduced tariffs on imports after the First World War. The domestic market also deteriorated and was significantly hit by a wave of imports from Japan and the Commonwealth countries. Despite the considerable decline, Lancashire mill owners believed that it was only a *temporary*

[2] The agreement to reciprocally-level tariffs or free trade between different Dominions and colonies within the British Commonwealth of Nations was introduced in 1932. After the Second World War the policy was gradually changed, as a result of American pressures, the General Agreement on Tariffs and Trade (1947), and Britain's integration to the EU in 1973 (Owen, 1999).

change and any major change was unnecessary (Tippett, 1969). Exports continued to target low-end markets with improvements concentrated on cost reduction through wage cuts, utilisation of lower quality yarns and longer working hours. The most common response adopted by the majority of the firms was the use of inferior cotton as a cost-cutting measure known infamously as 'bad spinning' and 'bad weaving'. This practice damaged the industry's credibility and created more problems for the industry such as a difficulty to attract quality workers. An option to re-tool the industry with more modern equipment, that is, with ring frames or automatic looms, was largely eschewed by the industry.

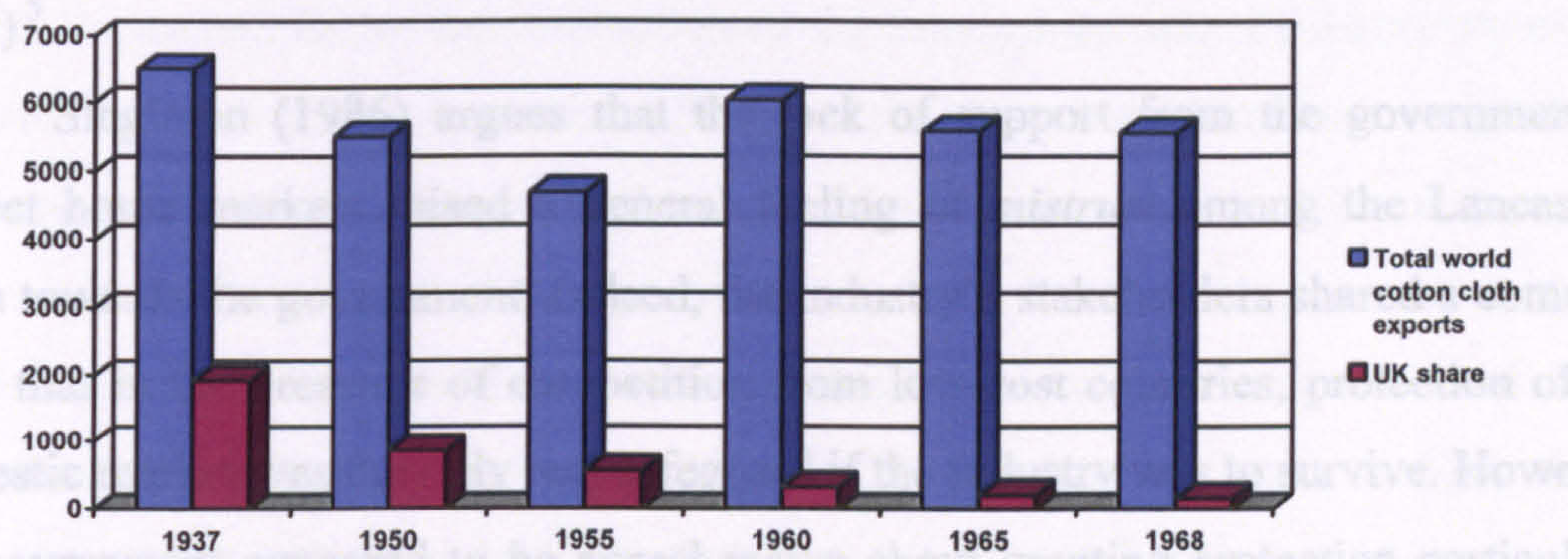
According Saxonhouse and Wright (1984), the propensity to use low quality yarns as the main strategy to reduce costs caused the firms stuck to the old technology, mule spindles. The more modern technology, ring frames, caused low quality yarns to break because of its high-speed production process. As a consequence, while the rapidly growing textile industries in Asia, USA and South America invested in the latest technologies Lancashire was locked-in to the old technology (Dupree, 1996, Mass and Lazonick, 1990).

Competitive decline, however, was not the only problem faced by the industry. As market share continued to shrink, the industry suffered from over capacity which was reported to reach 40 per cent. Firms had to reduce prices even further which forced the inefficient firms out of business. The condition called for government intervention to reduce capacity through the Cotton Spinning Act (1936) which forced firms to withdraw and destroy spindles (Fowler, 2004).

The decline was halted briefly following a brief boom after World War II because of global shortages of supplies of textiles and the industrial reconstruction of Japan up to 1951. The government introduced the Cotton Spinning (Re-equipment and Subsidy) Act (1948)[3] to reduce the productivity gap with the USA and to secure a voluntary restriction on imports from India, Hong Kong and Pakistan in 1958 (Owen, 1999). Under these favourable circumstances mill owners were not convinced of the need to re-tool and modernise their production technology. Its failure to act put the industry back at square one by plunging it into a very poor

[3] Under the scheme, the Government agreed to contribute 25 per cent of the cost of new machinery to firms who grouped themselves into 'manoeuvrable units' and who accepted the introduction of shift work and new methods of labour deployment (Owen, 1999).

market and financial situation (Fowler, 2004). The industry's position was further weakened following the creation of the General Agreement in Trade and Tariffs (GATT) in 1947 which forced the restriction on Japanese imports to be removed. In 1950 its share of the cotton cloth export market fell to 15.6 per cent. By 1958 Britain had gone from controlling 80 per cent of the world cotton product market in the 19th century to become a net importer for the first time since the Industrial Revolution (see Figure 3-1).



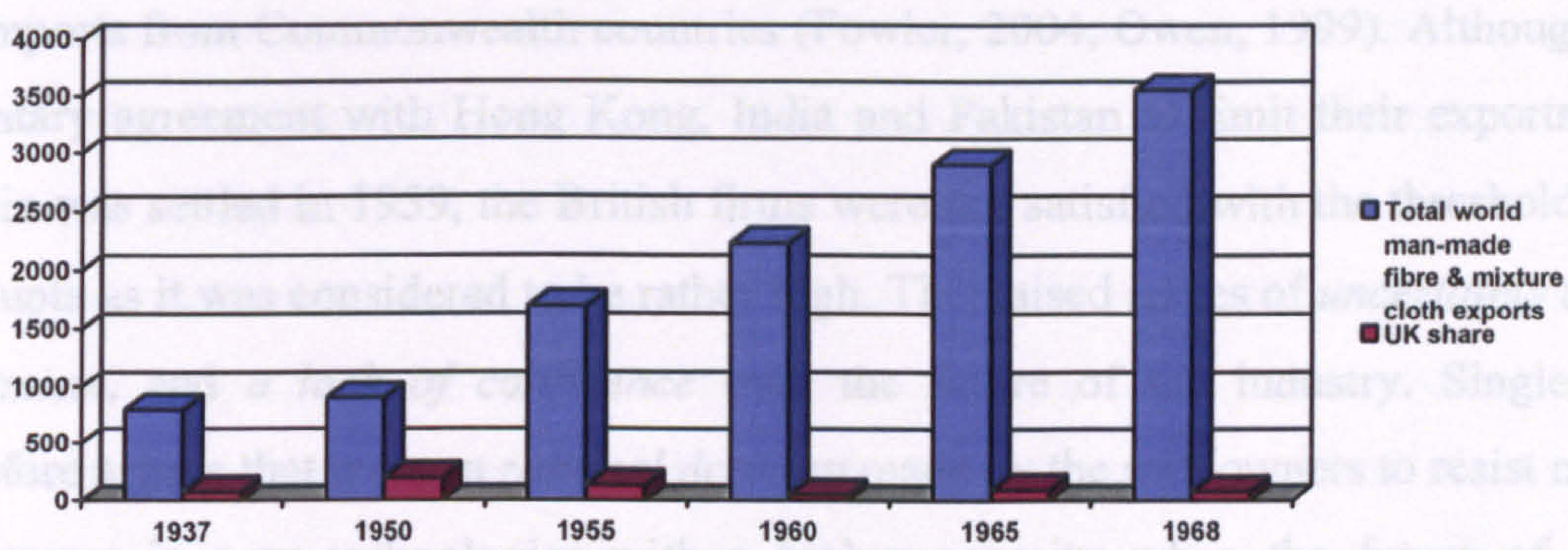


Figure 3-1. The share of UK cloth exports in world trade (cotton and allied textiles) in 1937-1968
Source: Cotton Board Quarterly Statistical Review; R. Robson, the Cotton Industry in Britain (1957, p. 359) in Singleton (1986, p. 96).

3.3 Causes of Decline

A combination of different factors which allegedly led to the inexorable decline of the Lancashire cotton industry has been discussed, all of which indicate the irreversibility of the decline. Central to the debate is the industry's technological backwardness which is assumed to be the main cause of the decline. A group of scholars argues that the obstinacy of the Lancashire firms to use older (mule) technologies was *a rational decision*, given ineffective government protection

(Singleton, 1986, Singleton, 1990), the *low incentives* (cost savings) for the adoption of newer (ring) technologies (Higgins, 1993, Saxonhouse and Wright, 1984, Sandberg, 1969, 1984) and the low suitability of the new technology to produce finer yarns (supra-40 counts) which represented around 40 per cent of the production up to 1913 (Leunig, 2001)[4]. The second group rejects this view and places the blame on the entrepreneurial failure and industrial organisation as the major contributors (Filatotchev and Toms, 2003, Owen, 1999, Lorenz, 1994, Rose, 1991, Lazonick, 1983)[5].

Singleton (1986) argues that the lack of support from the government to protect home markets raised a general feeling of *mistrust* among the Lancashire firms towards the government. Indeed, the industry's stakeholders shared a common view that in the presence of competition from low-cost countries, protection of the domestic market was the only real safeguard if the industry was to survive. However, the government appeared to be apprehensive about granting protection particularly for imports from Commonwealth countries (Fowler, 2004, Owen, 1999). Although a voluntary agreement with Hong Kong, India and Pakistan to limit their exports to Britain was settled in 1959, the British firms were not satisfied with the threshold of the quota as it was considered to be rather high. This raised issues of *uncertainty* and *pessimism*, and *a lack of confidence* over the future of the industry. Singleton therefore argues that it was a *rational decision* made by the mill owners to resist new investment in new technologies with a higher capacity when the future of the industry appeared to be uncertain. Other scholars also assumed that the obstinacy of the Lancashire firms to use the older technologies was a rational decision as the cost advantage from adoption was insignificant (Higgins, 1993, Saxonhouse and Wright, 1984, Sandberg, 1969).

Singleton further contends that under these circumstances, the government's programme for modernisation and rationalisation set out in the Cotton Industry Act

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[4] The market structure of yarns was admitted by Sandberg (1984) as a rough estimation. Different papers show different percentages for each type of yarn (see for example Sandberg, 1964, Lazonick, 1981, ad Saxonhouse and Wright, 1984). Owen, (1999) argues that the diversity of the market of the Lancashire cotton industry made mules more favourable mainly due to their flexibility to spin different counts of yarn.

[5] Singleton (1990) mentions that a pool of entrepreneurs might have enabled a new cotton industry to arise. However, he did not advance it as a factor that caused the decline of the Lancashire cotton industry.

(1959)[6] was largely ignored by the firms. Only 37 per cent of British looms were either fully or semi automatic in 1964, compared with 100 per cent in the United State, 69 per cent in France, 86 per cent in Italy and 86 per cent in Hong Kong. In 1954, Britain possessed 84 percent of all mule spindles in the world market but only less than 10 percent of the ring frame market. The US cotton industry, on the other hand, had completely scrapped their mule spindles.

Singleton goes on to say that given the growth of low-cost textile industries, notably Japan and India, the contraction of the Lancashire cotton industry should be expected as part of the industrial life-cycle. As those countries had a significant advantage of lower costs, cost had become the decisive factor of the competitive advantage in the textile industry. Singleton was less convinced that had the Lancashire firms adopted new technologies, they could have achieved large reduction in costs to maintain their competitiveness against the Japanese. He makes a bold argument that the demise of the industry should have been allowed even sooner because defending an uncompetitive industry led to economic inefficiency. The industry absorbed a significant amount of labour which would have been better off working in high-growth industries.

On the other hand, Lazonick (1981, 1983) strongly disagrees with Singleton's argument. He accepts the reasoning that market contraction was inevitable given the increased capability of the market countries to fulfil their own demand and that uncertainty hindered investment. Nevertheless, the fact that Britain's slow adoption of more modern technology was apparent not only during economically difficult periods - the inter-war years and after 1950s - upon which Singleton's argument was built, but also in prosperous times - the two decades prior to World War I and the short-lived boom period after World War II - indicated that pessimism was not the only factor that affected the low propensity to modernisation. Rather, it rested on more fundamental factors, that is, *technological interrelatedness* and its relevance to the structure of the industry.

Ironically, the industry's *vertically disintegrated structure* and *geographical concentration* which prior to 1914 had significantly contributed to *its long-term*

[6]The Cotton Industry Act (1959) introduced under a Conservative government provided subsidies for capacity reduction and modernisation (Owen, 1999).

competitive advantage was argued to be a serious constraint for the adoption of more advanced technologies (ring frames[7] and automatic weaving machines). According to Lazonick, the full advantage of high-speed, high-throughput machinery can only fully utilised within an integrated production system environment in which the flow of materials from spinning to weaving can be run uninterrupted. Otherwise, a number of additional costs such as transports would be incurred[8]. Furthermore, weaving mule-spun yarns in an automatic weaving machine caused yarn breakages as the yarns were relatively weak. This caused frequent production interruptions and incurred additional costs. Therefore, the adoption of automatic looms could only be justifiable with a guaranteed supply of low-breakage yarns that could only be produced with ring frames. As a consequence of this, the adoption of rings or automatic looms independently, as it happened in Lancashire, provides neither sufficient cost-savings nor high-throughput.

This argument was supported by Leunig (2001) who found that the rate of adoption of ring frames by integrated and co-located spinners and weavers was four times higher than that of specialised spinners without weavers close-by between 1880-1913. Given the technical complementarities between ring frames and automatic looms, this finding supports the argument of technical interrelatedness argued by Lazonick as one of the necessary conditions to gain the full advantage of the adoption of more advanced machineries.

Furthermore, Mass and Lazonick (1990) argue that the adoption of high-throughput machinery should be complemented with the formation of integrated mass marketing and distribution functions within an integrated organisation. These functions would help firms to attain and maintain concentrated market power and provide an incentive for the adoption of mass production systems. In brief, only in an integrated structure of production and marketing functions the incentive to adopt advanced machinery could be materialised. Given the industry's vertically specialised and geographical concentrated structure, the incentive to adopt the more modern technologies was poor.

[7] Ring frames spin and wind yarns in one action; therefore it can operate continuously. Mules, on the other hand, operate intermittently -spin and wind is performed sequentially (Leunig, 2001). Therefore, ring frames operate at higher speed and produce higher output per unit time.

[8] Sandberg (1964) explains that ring-spun yarns were wound on to wooden bobbins which cost much more and were heavier than paper cops on which mule-spun yarns were wound. Mules could even spin yarns without cops. For export markets, this would add transport costs.

In the context of a contracting market, fragmented structure instigated extreme competition among firms competing in the same market. As the adoption of advanced machinery was abandoned, firms adopted a cost-cutting strategy through the utilisation of low quality yarns and wage reduction to compete with the new competitors. This forced the spinners to compete against each other for comparatively small orders from several weavers which led to shorter production runs and overcapacity. The problem with excess capacity exacerbated the slow adoption of new technologies as the new machines would have increased the industry's capacity. Under such circumstances, it was economically justifiable to purchase low quality cotton to reduce costs and alter working practices (higher workloads and a double day shift system) to improve productivity. The spinners and weavers believed that their experienced workers would be able to offset the limitation of mules from the more advanced equipment.

Mass and Lazonick (1990) further argue that blaming low wages in the new textile producing countries as the culprit for the decline of the Lancashire cotton industry does not stand up to scrutiny. Wages per head in India were 10-15 per cent less than in Japan but it was Japan rather than India which emerged as the world's dominant textile exporter. India even needed protection to keep Japanese products out of their domestic market. Although lower costs definitely helped the country to compete with Britain, Japan's sources of competitiveness rested on its innovative capability to rapidly improve its textile production capability and productivity through, among other things, training, 24 hour production and, more importantly, rapid development of its own version of high-throughput machinery (ring frames and automatic looms combined). Japanese firms –pioneered by Toyoda and Mitsui- did not only import machinery from Britain, but more importantly, replicated and subsequently developed their own versions of spinning and weaving equipment. Their machines were lighter and cheaper than those of the British firms' and by the mid 1920s the performance of the Japanese machinery exceeded that of the British machinery. The superiority of the Japanese machines reached to the extent that Platts and Brother, the largest textile machinery maker in Britain from which Japanese firms initially imported their equipment from the 1860s, bought the right to manufacture Toyoda's machines in 1925 (Singleton, 1997). In addition, in contrast to the attitude of the Lancashire firms who accepted the limitation of ring frames to spin low quality yarns as it was and, hence, their reluctance to adopt the new technology, Japanese firms found a way to spin low quality yarns in ring frames. They developed a procedure to mix lower and higher quality cotton to allow the production of low breakage yarns at lower costs (Mass and Lazonick, 1990). This shows the innovative capability of the Japanese firms to turn limitations to their advantage. As a result of these innovations, Japanese firms' production costs per spindle which prior to World War I were the world's second highest after Switzerland, 40 per cent greater than India and 93 per cent greater than Britain were significantly reduced to compete favourably with these countries (Mass and Lazonick, 1990).

Japan's rapid adoption of high-throughput machinery was supported by its capabilities to change the structure of the industry from a cottage to a *vertically integrated.* Such a structure was built to support the government's aims to adopt mass production systems as part of a competitive strategy to gain market share in the international textile market dominated by Britain. The process of transformation was distinctly characterised by *state-led concerted efforts* involving all stakeholders – state, banks and firms - to build up a large and efficient integrated structure (Rothwell and Zegved, 1985). This resulted in a rapid restructuring process and a highly-concentrated, integrated and efficient industrial structure, as opposed to a vertically disintegrated structure in Britain. The integrated structure in Japan permitted control over the transaction between the different stages of the production process, allowing coordinated decision making. The structure also permitted planned coordination across the supply chain to allow continuous flow of production, optimisation of machine's capacity and high productivity (Lazonick, 1983). This system could not work in the fragmented structure found in Lancashire because firms had little control over the types and amount of cotton supplies and orders[9] and over the flow of the production process[10]. Japan's labour productivity rapidly

[9] This is related to the routines adopted by firms in Lancashire. Spinning managers bought cotton in Liverpool weekly without knowing in advance the quality of the available cotton; therefore they did not have control over the quality of cotton available in the market at any point in time. Orders were also placed weekly by marketing firms. This encouraged mills to work for short-term orders (Lazonick, 1983).

[10] In the vertically specialised and geographical concentrated structure, different production stages were linked by middle men. Ibid.

improved and eventually surpassed that of Britain. It took less than 50 years for Japan shift from being an importing country to the world's major textile exporter.

Japan's success in the industrial transformation is in striking contrast to Britain. Despite losing its competitive advantage in the cost-driven market, the industry continued to compete in the same market. The downside of this decision was the British cotton industry was trapped with its cost-cutting strategy and the production of low quality textile products. The majority of the firms eschewed any attempt to search for new markets where competition was not driven by costs,

Why did the British cotton industry find it difficult to change technologically and organisationally whereas Japan was able to successfully transform the structure of its industry and to adopt the system of mass production? It is probably true that the Japanese textile industry was far smaller than the British industry so that the necessary collective action to radically change the industry was more manageable. However, Lancashire's long experience, superior skills, more advanced textile machinery industry and well established support systems (services) theoretically should provide the industry with the necessary resources and assets –tangible and non-tangible- to respond sufficiently to maintain its leadership. Surprisingly, the supposedly advantages turned out to be the disadvantages when it became obvious that they were no longer appropriate for the new environment. This is because the traditions[11] became a constraint to change, the production skills to work with traditional equipment became entrenched, and the large infrastructure and well established routines became rigid. In addition, the vertically specialised and geographical concentrated structure limited communication between managers at the different stages of production. This hindered managers from learning from each other and from expanding their knowledge which eventually limited the possibility of vertical integration. Specialisation tended to be reinforced under these circumstances, impeding structural integration (Singleton, 1990, Mass and Lazonick, 1990). All these factors rendered the industry locked-into its existing structure, technology and market. This is in fact the nature of the maturity-trap (Abernathy, *et*

[11] Individual firms in the industry were used to belong to a family. In an extreme competitive environment, firm integration was refused by the majority of mills owners as it could entail sharing of power with other family members who involved in the merger. Consequently, collective actions required to radically change the industry was impeded as the mill owners were reluctant to give up their control in integrated mills. *Ibid.*

al., 1983), or described as active inertia (Sull, 2000) or core rigidities (Leonard-Barton, 1992).

Lazonick believes that the underlying factor that caused the decline of the Lancashire cotton industry was *entrepreneurial failure*, that is, the inability of the Lancashire managers to change the constraints which blocked innovation. Managers, *constrained by their inability to alter the technical and structural limitation* opted to stay in their traditional and yet uncompetitive markets. As competition in the market had to lower costs, the firms pursued a cost reduction strategy through more intensive use of their existing capital and resources. This is the fundamental difference in views between Lazonick and other scholars in the interpretation of the persistence of Lancashire mills to use mule spindles and power looms and the slow adoption of more advanced equipment compared to foreign textile industries. As discussed earlier, the majority of Lancashire mill owners overlooked the adoption of more modern technologies because they were capital intensive, incurred additional costs and, even worse, needed an integrated structure. In other words, the adoption of high throughput production process required radical change in both structure and practice, a condition which could not be provided by the Lancashire managers. The fact that the adoption of advanced machinery lead to dramatically lower unit costs was ignored by the Lancashire firms as a way to adapt to the changed competitive environment.

Entrepreneurial failure is also related to the inability to change *deeply entrenched values* that are no longer suitable in a different competitive environment. The tradition of maintaining absolute power over their family-owned firms has also been attributed to the resistance to integrate. The mill owners feared that integration would cost them their power and influence. Tippet (1967) explains that even in combined (spinning and weaving) firms he seldom found a self-contained firm within which the technical and managerial aspects were integrated. Instead, each function was run as a department or division with an individual degree of autonomy. The argument forwarded by the mill owners was that the combined firms were not economic because a spinning mill could not economically spin as wide ranges of yarns as required by a weaving mill to be profitable. Consequently, yarns produced by spinning mills in combined firms were sold to external firms while the weaving mills purchased yarns from other spinners. In other words, the synergy between the different production stages could not be achieved.

This individualistic culture which had characterised the industry since its heyday and the inability to change it hindered collective action necessary to radically change the industry. This situation was in striking contrast to the collective efforts made by the Japanese textile industry, which led it to dominate the international market by the early 1930s. It is important to note that it was the Japanese government policy which played a pivotal role in the transformation. The British government, on the other hand, was prepared to let the market determine the future of the industry. In hindsight, the government appeared to let the individualistic culture in any major way to persist and did not intervene to change it.

At this point, it is important to include another observation to the debate that supports the argument of entrepreneurial failure to the decline of the Lancashire cotton industry. In Lancashire and its surrounding areas, there were a number of firms such as Perseverance Mills (Lancashire) and Birley Brothers (Manchester) who managed to diversify into higher value-added products including rainwear, outdoor sports, military and extreme weather cloth and thrived in their new businesses (Rose and Parsons, 2005). Those firms survived the turbulence of the 1930s and 1970s and expanded their businesses. Unfortunately, the majority of the Lancashire firms did not have the entrepreneurial capabilities to search for new sources of profit through, for instance, the creation of new products and access to new markets. The finding highlights the severity of the maturity-trap among the Lancashire firms in that despite more creative and innovative attempts were underway in their neighbourhood they were completely overlooked or ignored by the majority of the firms. They could not appreciate the emerging opportunities well in advance and take advantage of them. They opted for the old same market, technology and strategy and requested more protection from the government which in the end did nothing for their cause.

These findings cast significant doubt over the validity of Singleton's argument that pessimism among the Lancashire owners and managers was the result of a judicious assessment of the slim possibilities of finding alternative routes to save the cotton industry. Indeed, there were alternatives to further contraction of the industry if mill owners and managers were aware about the emergence of new markets and had the innovative capability to seize the new opportunities. As Singleton correctly noted that (despite being rather contrary with his argument) there was always scope for 'true entrepreneurs' to take advantage and exploit new markets. However, he continues, success was the 'exception' rather than the 'rule' in the Lancashire cotton industry (Singleton, 1990). This suggests that Singleton somehow agrees that entrepreneurial failure was one of main factors which brought the industry to its knees. He does not discuss in great detail why success was an exception, however. If he had, he might have agreed with Lazonick that the 'exception' was due to the capability to break down the barriers to change and to look for new sources of profits.

The behaviour of the Lancashire managers and mill owners appears to be partly affected by their *short-term* business practices. According to Lazonick, a large number of firms operating in an extremely competitive environment could not see the importance of change for long-term competitive advantage as they were completely occupied by the need to grab relatively small orders for short-term revenues (Lazonick, 1983). This practice was not only used during difficult periods. In fact, it grew during the growth period when orders arrived continuously on a daily basis for short term deliveries. The practice of short-term orders and deliveries became routines as abundant high skilled labour, flexible equipment to work on small orders (mules and powered looms), specialised structure and geographical concentration enabled firms to meet such demand. Under these circumstances, mill owners did not have the incentive to develop plans for long-term growth. This practice became ingrained over a long period of time which caused inertia.

To put things in perspective, the mass production system introduced into the global textile industry by the US and Japan required an entirely different practice. The equipment and production system was geared for long production runs. The system could provide significant profits when large orders were placed. This required procurement and production plans to guarantee the availability of raw materials and on-time delivery. Therefore, to change from one production paradigm to another required a concerted effort from all the stakeholders. This proved impossible to implement in the Lancashire cotton industry because of the number of different factors discussed earlier.

The experience of the Lancashire cotton industry vividly illustrates the complementarities between markets, technologies, skills, structures and practices (routines). As a consequence, a change in one aspect would require changes in other aspects accordingly to gain the optimum benefit. As argued by David (1994), in an organisation (firm, industry, or country) such interlocking elements which constitute the organisation slow down the process of change. Moreover, it increases the risk of lock-in to the existing structure as firms tend to opt for the status quo. Therefore, large firms operating in mature industries where all elements and their linkages have been firmly established are vulnerable to falling into the maturity-trap. Failure to change – or entrepreneurial failure - fits very well in the argument of the maturity-trap. The example also shows the cost borne by the British economy for failing to change the fortunes of the industry and the role played by the government in this matter.

In brief, although pessimism may have influenced firms' decision making as Singleton argues, Lazonick has identified more fundamental factors which are the real culprits of the decline. Lazonick's argument is highly *historical* in that industrial inertia was caused by a well-established structure and routines, and deeply ingrained values and practices which were built up over a century and had brought success to the industry. For our purposes here we concur with Lazonick on the grounds that his argument gravitates towards the phenomenon of the maturity-trap although he does not refer to the phenomenon *per se*.

3.4 Structural Change and 'Mismatched' Strategy

From the late 1920s, the government played a central role in the attempts to restructure and rationalise the Lancashire cotton industry. The government encouraged amalgamation or horizontal integration and the removal of inefficient looms aimed to reduce capacity and ease price competition among the Lancashire firms. The attempts however failed to improve the industry's competitiveness prior to the 1960s. If Lazonick's diagnosis to the problem is accurate that the industry needed to integrate vertically to compete with Japanese products, the policy was not sufficient as amalgamation failed to encourage vertical integration.

The direction of restructuring and rationalisation attempts changed dramatically after 1964. The government, deeply concerned with the sustained decline of the industry, was inspired by the reorganisation model of the US which suggested that a vertically integrated structure was a necessary condition to adapt to the new environment. It was believed that strong groups of integrated, multi-fibre, multi-operation textile manufacturers would make the industry less vulnerable to the fluctuations in demand and help to realise economies of scale (Owen, 1999). The government approached fibre producers to initiate and drive industrial restructuring. Large chemical fibre producers, especially Courtaulds and ICI, were the leading firms which drove structural changes in the industry through a wave of mergers and acquisitions. For the fibre producers, particularly Courtaulds, the acquisition of Lancashire firms helped secure the market for its fibres as cotton spinners and weavers were its major customers. The initiative resulted in structural change towards vertical integration and a higher concentration ratio. The concentration ratio reached 50 per cent in the spinning sector in 1968, an increase by 18 per cent from the ratio in 1958, while the ratio of the weaving sector increased from 12 per cent to 31 percent. The invasion of man-made and synthetic fibre producers in the textile industry increased the utilisation of man-made and synthetic fibres whereas the proportion of cotton yarns and products steadily declined (Lazonick, 1983).

Courtaulds, however, found that restructuring and rationalisation on its own was insufficient to improve the industry's competitiveness. The firm appealed to the government for protection from imports from developing countries on the grounds that it was justified while the industry was being re-organised. The appeal was accepted and the government took the lead to promote an agreement among exporters and importers to limit the growth of imports from developing countries to 5 per cent a year. This agreement led to the introduction of Multi Fibre Agreement (MFA) in 1973. The policy instrument, however, did not deal with the greatest anxiety of the industry, that is, Britain's duty-free imports from the Commonwealth countries. Despite concerns about offending the Commonwealth countries, the government eventually imposed tariffs on Commonwealth imports in 1972 (Owen, 1999).

The restructuring towards vertical integration shows that the industry has resolved problems with the fragmented structure as argued by Lazonick (1983) as the fundamental cause of the decline. If his argument is correct, the Lancashire cotton industry should have regained its competitiveness and competed successfully in the traditional textile market and should have halted or reversed the decline. The reality of the situation was something very different from the early expectations. Vertical integration had little impact, if any, on the long-term improvement of the industry's profitability. In 1980 cotton production hit a historic low of 399 million yards and 327 million yards for cotton and synthetic fibres respectively. Compared to its peak, cotton production in 1980 only accounted for five per cent of that in 1912. Likewise, employment in 1980 only represented 12 per cent of that in 1910.

This fact raises a doubt over the accuracy of Lazonick's argument. Although his diagnosis of the problems appears to be quite convincing, the prescription needs further examination in accordance to the circumstances under which it is applied. Between the 1910s-1960s, during which the mass production system revolutionised the global textile industry, a vertically integrated structure as he suggested was probably the competitive solution. The new system proved to be vastly superior compared to the British traditional craft-based system for the production of low-value, high-volume products. From the 1970s onwards market trends changed towards more fashionable products characterised by frequent changes in design and style. The new trend required flexible manufacturing systems to enable manufacturers to respond rapidly to seasonal fashion demand. Italy was the pioneer of this new concept which could only be achieved with a less concentrated structure where small and medium sized enterprises were clustered in a number of industrial districts within which they worked together in networks. Italy's distinctive industrial features fitted well into the new trend whereas a more concentrated structure as found in Britain did not as large firms tend to be inflexible.

The new fashion concept introduced by the Italian fashion designers is called prêt a porter (ready to wear). The concept revolutionised the fashion system used to be dominated by the Parisian *haute couture* (made to order). As discussed in Chapter 1, the adoption of high-throughput machinery from the US transformed the Italian designers' couture capability to ready to wear. The emergence of the new fashion concept was encouraged by the new demand for lower-cost solutions of high quality fashion products. The demand was driven by mass consumption in the US which emerged during the economic boom after the Second World War. The solution can be achieved by combining Italy's traditional craft-based system with the mass production system imported from the US. The latter was part of the Marshall Aid Programme from the US government for the restoration of Italian industries after World War II. The new concept rapidly gained in popularity as it facilitated the production of stylish clothing at more affordable prices.

This new fashion system did not only revolutionise the fashion industry but also shifted the power within the textile and clothing supply chain away from the manufacturers to designers. Benetton was the icon of this new era. As its distinctive industrial features fitted well into this new trend, Italy possessed a relative competitive advantage compared to other countries. For the next three decades, Italian designers dictated the market with their seasonal ranges (summer, autumn, winter and spring). A large number of new design houses such as Dolce and Gabbana, Armani, Cerutti and Versace to name a few emerged in Italy for which Milan emerged as the Capital of Fashion.

The British textile industry which had neglected the European market for decades was not in a position to respond quickly. The industry overlooked the development of their neighbours and reverted to the outdated strategy of its counterpart across the Atlantic (USA) which appeared to be unsuitable for the prevailing conditions in the European market. In fact, the British textile industry did not adopt the American strategy as it was. Britain integrated the entire production process from fibre to garment production whereas the US remained separate fibre production from textile manufacturing. Consequently the British structure was arguably more rigid and inflexible to changes in the business and economic environment.

Yet again, history was about the repeat itself as the industry once again failed to recognise potential changes in demand and technology in advance and to identify appropriate ways to respond. This 'mismatch' between market trends, structure and technology caused by misreading potential changes had a devastating impact on the industry. Having lost ground from the low-cost countries in mass-produced markets since the 1930s, the British textile industry now found itself insufficiently equipped with the technology, structure and capability necessary to compete in the fashion market. The extent of the damage was very severe. Courtaulds and other large textile firms including Viyella and Coats Patons found themselves in a very difficult situation. Courtaulds, because of its heavy dependence on the Lancashire cotton industry and on its cellulosic fibres, had to significantly downsize from 1980 and to relocate a large portion of production abroad. The firm was demerged into two different firms –textiles and fibres-chemicals- before the textile business was acquired by Sara Lee in 2000 who subsequently sold to it to a Hong Kong group, PDE Enterprise, in 2005. Its chemical business was acquired by one of its former competitors, AkzoNobel, in 1998.

A small number of Lancashire firms actually managed to escape from being acquired by large firms and survived when Courtaulds was struggling to reorganise. Rose and Parsons (2005) identified that firms which survived in Lancashire were smaller in size and pursued specialised, high value-added products where competition was less determined by costs. They diversified into high-performance and technical textiles, notably rainwear, outdoor sports, military and extreme weather cloth. Demand in these markets emerged in the years leading up to the First World War, and grew progressively after the 1960s. As discussed earlier, a number of traditional Lancashire firms such as Perseverance Mills (founded in 1901) and Baxendan Chemicals, and Manchester-based cotton manufacturers Birley Brothers and R.W Barton foresaw these new opportunities and decided to create new products rather than following the majority of their competitors. Since World War I they have successfully diversified their products to include fabrics for the military (balloon fabrics, parachutes), extreme weather, and outdoors (such as sleeping bags).

They made the transition within a relatively short period of time. To illustrate the point, during World War I, Perseverance Mills supplied barrage balloons to guard against anticipated German air raids, although up to 1914 it still exported grey cloth to India. The transition was made possible because it applied accumulated knowledge generated from its experience in the production of grey cotton cloth to make goods demanded in new markets with different specifications. The firm combined its traditional knowledge, for which they were the best in the world, with new materials (nylon) to fulfil demand in emerging markets. From the outset, the firm licensed or purchased fibres to make breathable waterproof fabrics from DuPont and W.L. Gore (GoreTex®). They wove or knitted the synthetic yarns into performance fabrics with close cooperation with their clients. Over time, Perseverance Mills learned and improved its learning and absorptive capacity to make its own specialised fabrics, Pertex®, the market leader in water resistant, lightweight and highly breathable fabrics. Interestingly, the experienced spinners and weavers which were claimed to be the obstacle in the adoption of more modern machinery due to their inappropriate skills to run the new machines (Saxonhouse and Wright, 1984) turned out to be a great contributor to the process of diversification. In fact, their experiences were the critical assets during the new product development process. This illustrates the entrepreneurial capabilities which facilitate firms to break down the barriers to change and to profit from them. These capabilities, however, were rarely found in the Lancashire firms (Lazonick, 1983).

3.5 The Maturity-Trap at the Firm Level: Lessons from Courtaulds

As mentioned in Chapter 1, the debate about the decline of the British cotton industry which mostly focuses on the condition at the industry level lacks of the analysis of the inner workings of business enterprises which contributed to the decline. It is argued that a lack of such knowledge disregards the underlying factors necessary to analyse the process which leads firms to fall into the maturity-trap, the fundamental cause of decline. In addition, the firm level analysis permits the analysis of firm's dynamic capabilities to examine the source(s) of a sustainable competitive (dis)advantage (Teece, *et al.*, 1997).

The historical development of Courtaulds, the largest group of textile manufacturers in Britain between the 1920s-1960s, is the most appropriate case to illustrate the process of the maturity-trap at the firm level. The firm which used to dominate (in fact, monopolize) the market for viscose and acetate rayon in Europe as well as the largest producer in the US fell victim in the face of a changing business environment. Competitive threats posed by synthetic fibres, that is, polyamide and polyester developed by DuPont and ICI respectively, played a significant role in the decline of the rayon market. With the growth at around 8-10 per cent per annum, synthetic fibres took over the share of rayon in its main market, that is, garments and tyre reinforcements. It is argued that the firm's inability to adapt to the new competitive environment appears to be fundamental to its demise in the late 1990s. Courtaulds, an old and large organisation, fell victim to its old strategy which had brought success to the firm but was no longer competitive in the face of the emergence of new competitors. Organisational inertia led to poor business decisions which eventually plunged the firm into crisis. A number of attempts to save the firm were made but the results were very disappointing. There is a strong indication that the failure of Courtaulds was fundamentally caused by the maturity-trap. The following section analyses the issues of maturity-trap at Courtaulds in greater detail.

Courtaulds enjoyed exceptional growth between the 1920s-1940s following its decision to license the production process of viscose rayon for the British and US market in 1904 and 1911 respectively. The decision was initiated by the entrepreneurial management who foresaw that the future of the firm was no longer in the silk mourning crepe, its traditional business, as the market had stagnated in the 1890s. The firm realised that the decline of its traditional market was permanent and that it needed to change direction and capitalise on emerging technologies and markets. Viscose rayon which was invented in 1894 was an ideal replacement for silk and, moreover, provided an opportunity to enter different markets. The acquisition of viscose rayon led to a radical change in the firm's knowledge, technology, product and market. Courtaulds was the first firm to commercialise viscose rayon.

When the firm faced a changing market for the second time Courtaulds' entrepreneurial attitude and strategy however appeared to be lacking. The arrival of synthetic fibres in the market saw the growth of its viscose rayon business decline considerably. The market experienced a long-term decline up to the acquisition of the firm by AkzoNobel in 1998. Prior to the Second World War, viscose products contributed to 80-90 per cent of the firm's profit. In less than two decades the figure dropped to 30 per cent. The situation was exacerbated by increased competition in viscose rayon as a consequence of the diffusion of relevant knowledge and lower entry barriers to the market. Under these circumstances, price competition intensified as capacity soared.

Its distance from the development and commercialisation of polyamide and polyester excluded the firm from the opportunity to capitalise from the period of rapid growth which was monopolised by DuPont and ICI. In fact, ICI declined Courtaulds' request to license the technology. To make inroads into the synthetic fibre market, Courtaulds made attempts to develop its own version of acrylic fibres, Courtelle, and a few other fibres after 1955. Courtelle was Courtaulds' most successful synthetic fibre as it could improve the performance of its garments through blending with other fibres. However, the introduction of Courtelle in 1958, several years after DuPont and Monsato established their acrylic markets was a poor product development strategy. The prowess of the two competitors in R&D in synthetic fibres and their strong financial resources impeded the growth of Courtelle. Arguably, Courtaulds was falling into the maturity-trap as it refused the option to make a radical departure into synthetic fibres as DuPont did[12] despite clear indications that the future of cellulosic fibres was under serious threat. In contrast to its decision to enter the viscose market at a very early stage its decision to enter the synthetic fibre market was considered to be too late.

Under these circumstances, Courtaulds was forced to concentrate on its main market despite the severity of the decline and the maturity of viscose technology. The firm ruled out the possibility that the decline was permanent and contended that rayon staple fibres offered the most hopeful prospects (Knight, 1974). The firm believed that the changing environment was temporary partly due to a change of fashion and the end of the post-war boom. Therefore, incremental innovation such as price reduction, quality improvement and aggressive marketing could overcome the problem. To some extent the strategy arrested the decline but it definitely did not halt it (Boisot, 2002). In terms of R&D, Courtaulds maintained a focus on the improvement of processing cellulosic fibres until the 1990s although its performance appeared to have stagnated after the invention of high tenacity rayon in the 1940s and high wet modulus rayon in the 1950s (Boisot, 2002).

In 1955 Courtaulds launched a new strategic movement to expand its rayon market and to look for other alternative areas for growth through acquisitions. The firm acquired British Celanese, the producer of acetate products, in 1957 to ensure its dominant position in the rayon market. It also entered paint, packaging (cardboard, plastics and can), steel tyre cord, and glass fibre and fabric markets between 1958-1960. The result of the expansion and diversification strategy was not as expected. The performance of the new divisions was poor despite significant investment. The firm was over-optimistic regarding the size of the market and misread competitors' responses to its strategy. Metal Box, a competitor in open-top can packaging market, launched a

[12] DuPont diversified its business from gun powder to rayon through a licensing agreement with the French Comptoir des Textiles Artificiels in 1920. As the market of rayon declined DuPont scaled down its rayon operation and eventually closed the operation in 1960.

costly battle which forced Courtaulds to sell the majority of its ownership in Reads, its can packaging firm in 1967.

The Board's reluctance to shift to a decentralised structure despite its inability to properly manage such diverse businesses with a centralised structure contributed significantly to the failed attempts at diversification (Coleman, 1980, Knight, 1974). Centrally controlled management of highly diversified businesses generally involves complex bureaucracy. Management often fails to recognise problems early on, thereby delaying any attempt to fix them. In addition, Knight (1974) suggests that the firm's inability to overcome the complications during the process of integration of the acquired firms into Courtaulds' management systems, cultures and practices was fundamental to the failure. He believes that the knowledge of Courtaulds' managers could not instantly be applied to the new businesses at least in the beginning. The managers needed to learn the conditions and practices specific to the relevant industries and markets. In a similar fashion, the managers from the acquired firms needed to be introduced to a new management style and culture. It appears that Courtaulds' management could not recognise the complications which arose from acquisitions.

The story of Courtaulds vividly illustrates how a large, ambitious firm can fall victim to the maturity-trap when confronted with a changing competitive environment. The adoption of viscose rayon had strategic implications for the firm's structure and practices which was ignored by the management when the market for rayon started to decline. By moving up the value chain to produce man-made fibres and the increasing importance of the fibre business to its turnover, Courtaulds gradually reduced its involvement in its traditional business, that is, the production of fabrics and garments for end users (Knight, 1974). As the firm considered itself a textile firm regardless of the fact that its main product was chemically-modified cellulosic fibres, Courtaulds did not build up a research capability in basic chemistry as DuPont did (Owen, 1999). Rather, it decided to strengthen its competence in the commercialisation process of new fibres discovered elsewhere which was exceptionally successful in the commercialisation of viscose (Boisot, 2002).

The strategy worked well in the adoption of viscose where Courtaulds was the first firm which took the risk to commercialise the new fibre at an early stage. As the subsequent developments of fibres came from R&D in basic organic chemistry its decision not to invest in fibre chemistry put it behind any new developments. Moreover, the presence of the new competitors –DuPont and ICI which came from the chemical industry- characterised by advanced research capability in chemistry, large size and a financially strong organisation –in contrast to the characteristics of textile firms- left Courtaulds with little opportunity to commercialise the new fibres. DuPont and ICI developed and commercialised new synthetic fibres themselves and gained a temporary monopoly during the growth period whereas Courtaulds was left behind. Its joint venture with ICI to commercialise nylon –British Nylon Spinners (BNS)- fell through which provoked Courtaulds to sell its share in BNS to ICI in 1964 in exchange of ICI's holdings in Courtauld's equity. Although it developed a different production process to produce nylon 6 ('Celon'), the commercialisation had little effect on the firm's profits. This illustrates how striking to an old strategy in a different competitive environment can prove to be absolutely fatal.

Courtaulds failed to respond effectively in the face of new competitors from outside the textile industry who brought in new products performance in to the existing markets derived from a different technological paradigm. Its insistence to remain in its traditional textile market was typified by greater emphasis on processes improvement and niche market diversification excluded the option to diversify organically away from its established businesses. Its competence was not sufficiently broad or diverse. This rendered the firm more vulnerable to changes in both markets and technology and was at risk of losing a large share of its revenues if there was any significant change in the former or latter.

Courtaulds' experience was in striking contrast to that of DuPont. DuPont successfully transferred its chemical R&D capability (established in 1903 with the formation of Central Research) in gun powder and rayon fibres into synthetic polymers through the establishment of a fundamental research programme in 1927. As the rayon market had reached maturity, DuPont sold its rayon business in 1960 and concentrated its R&D efforts on the emerging synthetic polymers. This shows that DuPont's agility and flexibility towards change saved the firm from disaster as the market for gun powder gradually disappeared following the conclusion of the Civil War.

The decision to ignore R&D in fibre chemistry had further ramifications for the firm's plight. It became detached from the development of synthetic polymers and its decision to focus on the expansion and improvement of rayon fibres. The fact that rayon had lost its competitiveness to synthetic fibres and opportunities for technical improvement were limited was ignored. As the majority of its staple rayon production was consumed by the textile industry, the decline of the Lancashire cotton industry posed a serious threat to its revenues. Therefore, forward integration into textile manufacturing was deemed to be the only sensible option to secure its future. As discussed earlier, other alternative paths such as diversification and entry into the synthetic fibre market failed to have any considerable effect on the firm's profitability. Moreover, this strategy was to show to the City of London that Courtaulds had found a new path to grow following the bid by ICI which was rejected in 1961.

Courtaulds' management was convinced that an injection of capital, modernisation and modern management style would help the Lancashire textile firms to compete with low-cost imports in the European market. They believed that scale and standardisation for long production runs of standard fabrics were the key competitive factor in the global textile trade (Owen, 1999). The firm was encouraged by the British government to lead mergers and acquisitions of the Lancashire firms to form large groups of integrated textile manufacturing firms. As discussed earlier, this business strategy was inspired by the successful restructuring programme in the US textile industry. The management at Courtaulds assumed that the same strategy could be applied in Britain. They ignored the fact that the market structure and demand between Europe and the US were different and this would affect the effectiveness of the strategy. In contrast to the US market which was more homogenous the European market demanded more differentiated, stylish and fashionable fabrics. Therefore, a large integrated structure was less suited to the competitive environment in Europe. Management also made an ill-based assumption that the integration of the entire textile production process (from fibre to textile or garment manufacturing) would generate synergies and increase the competitive advantage of the British textile industry (Owen, 1999). They also misjudged the capability of low-cost countries to put even greater on Western producers even after they had reduced prices.

Indeed, the extraordinary wave of takeover activities which began in 1962 (see section 3.4) could not restore the competitive advantage of the British textile industry. The recession post oil shock in 1973 caused a significant decline in demand. The entry to the European Common Market (now the European Union) which coincided with the recession exacerbated the problems faced by the industry. Contrary to its initial intention to replace imports from low-cost countries, the firm found its standardized products unsuitable for the heterogeneity of the European consumers. It failed to capitalise from the Common Market as it lacked experience in marketing and distribution of textiles on the Continent.

The new management in 1975 abandoned the vertical integration strategy. The firm initiated rationalisation, reorganisation and redirection over the next two decades. The unprofitable (traditional) businesses were sold, the textile and chemical businesses were demerged into two different firms and greater focus was put on the fields where Courtaulds had a technical advantage over its competitors. Despite these attempts, the chemical business, comprising of fibres, packaging materials and paints, was acquired by the Dutch chemical group, AKZONobel, its competitor in the improved rayon fibres, in 1998. Meanwhile, its textile operations started to outsource production to cheaper overseas locations. Its long-term business relationship with Marks & Spencer guaranteed a steady flow of orders in the domestic market, yet it failed to prevent the textile business from being acquired by Sara Lee in 2000.

Interestingly, the maturity-trap did not only affect Courtaulds traditional textile market but also in the carbon fibre market. Courtaulds was one of a few firms which initiated the commercialisation of carbon fibre in Europe in the mid 1960s. In fact, Courtaulds was the largest carbon fibre producer in Europe up to the 1980s, accounting for 90 per cent of European carbon fibre production and it seized 13 per cent of the world market (Spinardi, 2002). The firm, however, failed to maintain its leadership despite full support from the British government and ceased its carbon fibre production in 1991.

Courtaulds entered the carbon fibre market following the invention of the process to produce high strength, high modulus and highly orientated crystalline carbon fibres by the UK Royal Aircraft Establishment (RAE) in Farnborough in 1965. It found that polyacrilonitrile (PAN) fibres could be used as the precursor to carbon fibre production. The government, who was keen to avoid yet another British invention being exploited more successfully overseas and encouraged Courtaulds to be the supplier of the precursor for the RAE[13]. Courtaulds was an obvious candidate to be a supplier of PAN as it was the largest supplier of 'British' acrylic fibres (Courtelle). PAN was a variant of Courtelle and was produced using a similar process to manufacture Courtelle.

[13] Please refer to Colombo U (1977) Strategies for Europe proposals for science and technology policies industrial innovation in Europe. Omega 5, 511-527.

Within two years of its involvement in the production of PAN, Courtaulds became the producer of carbon fibre.

Courtaulds' process had a cost advantage over other processing methods. Nevertheless, its aqueous spinning process was vulnerable to inorganic impurities in the water supply. This impurity had a great adverse impact on the strength of the resulting products. For instance, it caused carbon fibre turbine blades of Rolls-Royce (RB211) failed the bird strike impact tests in 1967-1969. This problem caused by the impurity of PAN was not identified by RAE until the 1970s (Spinardi, 2002).

The impurity issue caused Courtaulds to lose out on the high end market (aerospace). Rolls Royce, for instance, shifted to Japanese suppliers which produced high purity carbon fibres. Yet its lower cost solution and large production capacity appealed to other markets (sporting and leisure goods) which started to pick up in the late 1970s. The support from the government to increase production capacity helped the firm to reduce the price even further (Knight, 1974). By the end of 1980s the sporting and leisure goods markets represented about two third of production while the rest was for the aerospace industry, particularly for British Aerospace (now BAe Systems).

Courtaulds' competitive advantage, however, became a weakness when the market changed against it in the early 1990s. The decision to exploit low-cost PAN and pursue mass markets in sports applications (75 per cent of its production went to Taiwan and Korea by the end of the 1980s) made it more vulnerable to competition from low-cost countries, mainly Japan and Korea. Meanwhile, its large investment in the US in carbon fibres and the subsequent processes, that is, prepreg and composites, failed to generate healthy returns. Its assumption about the growth of demand in the US military market never been materialised following the end of the Cold War. Subsequently, the firm suffered from huge overcapacity and loss of profits. Courtaulds lost faith in carbon fibres and sold its production units in the US and UK in 1991. Meanwhile, the late-comers such as Toray, Toho-Tenax and Mitsubishi Rayon, emerged as the world's largest (small tow) carbon producer which offered better products (purities) and more cost-effective production processes. Together they seized 72 per cent of the global market in 2007. Toray alone had the largest share (Roberts, 2007).

How did a large firm which dominated the European market and controlled a significant global market share fall victim to competition from low-cost firms? The answer is the classic maturity-trap. The downturn in global demand certainly adversely affected the firm's performance; however, the firm's reluctance to change, ill-judged business decisions and a short-term business strategy appears to have caused permanent damage to the firm (Spinardi, 2002). Courtaulds declined to shift from the aqueous-based spinning process although the impurity resulting from the process weakened the strength of the fibres. This made the fibres unsuitable for the high-performance market such as the aerospace industry. A request from Rolls-Royce to provide samples for its aeroengine pod doors in 1979 was declined by Courtaulds on the grounds that the requested fibres could not be produced by its established processing technology and the size of the order was too small. Courtaulds contended that any change which could cause disruption to its continuous production process was uneconomic. It was reluctant to establish small production facilities to deal with development projects that were different from its established products and technologies. This shows that its reluctance to change hampered the opportunity to receive orders from the aerospace industry which offered higher margins but demanded higher strength carbon fibres.

Ironically, Rolls-Royce became an important market for the Japanese carbon fibre manufacturers. In fact, Toray became an important supplier for the main players in the aerospace industry, Boeing and Airbus (Spinardi, 2002) whereas Courtaulds missed out on this opportunity as it concentrated on low-cost products and the US military market. As with the Lancashire cotton industry, this strategy made it vulnerable to competition from low-cost competitors (Japanese and Taiwanese producers).

Furthermore, its large investment appears to have forced management to pursue quick returns. As argued by Rosenberg (1996), new technologies entail uncertainties in market and technological performance. Therefore, it is highly risky to invest at large amount in one market and technology at the early stage of market and technology development. In the case that the assumptions on which the investment was based failed to materialise, and hence low return on investment (ROI), the firm lost its confidence. This led to Courtaulds' withdrawal from the carbon fibre business. Hayes and Abernathy (1980) argue that relying heavily on short-term financial measurements such as ROI reinforces short-termism which had serious detrimental effects on the US manufacturing in the 1970s.

Interestingly, the Japanese firms had a very different approach. They maintained their investment in diversification, capacity expansion and cost reduction although the global down turn caused severe overcapacity and loss of profits. This behaviour was driven by its expectation of long-term gains rather than short-term profits. Despite many years of marginal profitability Toray management still believed that the carbon fibre market would pick up and the most profitable market would be in the high performance market. Instead of following other big competitors to pursue the US military market Toray improved its capability from producing carbon fibres for low-technology applications to high-technology applications particularly for the European aerospace industry (Spinardi, 2002).

The rise and decline of Courtaulds clearly exemplifies the consequences of falling victim to the maturity-trap. The firm's responses to the changing competitive environment were ineffective to ensure its survival due to outdated R&D and business strategy, poor management and an inappropriate organisational structure and practices. The application of the same strategy, management style, business structure and practices which used to bring about success to the firm (in its rayon business) and yet were no longer suitable in a new competitive environment led to its demise. Its deeply entrenched values and practices that have been built over a long period of time hindered more radical responses which might have saved its future.

3.6 The Maturity-Trap: Lessons from the Past

What can be learned from the decline of the British textile industry and Courtaulds? A number of factors that triggered the loss of the competitive advantage of the Lancashire cotton industry in the face of rising competition from Japan, the US and India have been identified. Uncertainty which caused pessimism over the future, low-level of investment leading to technological backwardness, ineffective government policies, fragmented industrial structure, a lack of collective actions and inability to accurately recognise trends have been cited. Above all, the underlying cause of the decline was the industry's distinct structure, values and practices that had been very successful over a long period of time and had reinforced each other to become deeply entrenched. When the environment changed rapidly, managers who could not change the traditional structure, values and practices, confined their responses to the areas they knew very well and became locked-in to the existing structure, practices, technology and market. This is the very nature of the maturity-trap.

The determination of the Lancashire firms to continue to pursue the cost-cutting strategy to compete in the market it used to dominate despite the loss of its competitiveness clearly illustrates the maturity-trap. Instead of searching for new markets the industry brought its reputation into disrepute by the use of low-quality yarns, the reduction of wages and the extension of working hour to reduce costs. The strategy neither helped the industry to regain its competitive advantages nor did its reputation any good. The poor reputation caused the industry to lose its attractiveness to highly-skilled workers which by implication damaged the industry's competitiveness even more. In this case, the maturity-trap caused a spiral downward effect which eventually led to its terminal decline.

The cost-cutting strategy became a common practice among the firms since the growth period in the last two decades of the 19th century. As discussed earlier, the number of firms competing in Lancashire created an extremely competitive environment as the firms located in the same district produced the same products, used the same technology and raw materials, followed the same strategy and perceived competition based on the same assumptions. The pressure to imitate each other was high, leaving price as the main differentiating factor. Therefore, it is hardly surprising that the managers opted for cost reduction in search of short-term profits at the expense of more radical alternatives for long-term growth. The attachment of the firms to this strategy was severe to the extent that they failed to recognise the serious deficiencies of the strategy to retain their competitive advantage when new more nimble competitors emerged. This underpins the argument that *poor leadership*, *myopic views* of the owners and *entrepreneurial failure* are the underlying factors of the maturity-trap at the *firm-level*. These factors are also highlighted in the decline of Courtaulds.

The study of the British textile industry and Courtaulds vividly illustrates a large industry and an iconic firm falling into the maturity-trap. It is important to note that the firms were not necessarily unresponsive to changing environments. On the contrary, they put considerable efforts in to respond to the changes. However, the attempts were insufficient to maintain their leadership, were misdirected as they misread emerging trends, were too late or were based on ambitious assumptions to gain quick returns.

With regards to the debate about the cause of the decline of the Lancashire cotton industry, this study offers a different perspective. Had the Lancashire cotton industry managed to change its structure and adopted modern technologies in time or changed its direction to more fashionable products, would the industry have thrived? It is far from clear whether the industry would have been able to compete in the coarser textile market dominated by Japan, India, and the US or in the fashion textile market controlled by their European competitors notably Italy, France and Germany. In either case, the industry needed to build up new capabilities and create a new industrial structure because the prerequisites for the two extremely different markets were not readily available to the British textile industry. For instance, it is the basic requirement in the fashion market to have a pool of fashion designers who work closely together with textile manufacturers to develop new designs on a frequent basis. Close relationships between textile manufacturers and machinery manufacturers are also necessary in the development of flexible equipment to enable them to adapt to frequent changes in trends. In Italy, such relationships have been evolving since the late 1940s and handed a unique competitive advantage over Britain. In Britain, on the other hand, little collaborative efforts have been made between the British textile machinery makers with the textile manufacturers. The former, although leading the global market up to the 1930s, exported the largest portion of its production as the domestic industry rather slow to adopt more modern equipment.

In the coarser textile market, had the industry changed its structure and production system early enough to compete with the mass production system, the Lancashire cotton industry might have been able to prolong its dominance for several more years as its productivity could have increased significantly. Under such circumstances, Japanese firms might have required a longer time to catch-up with the level of productivity of the Lancashire firms. However, given the maturity of the textile technology which permitted competitors to purchase off-the-shelf technologies and the diffusion of know-how in textile production, Japan would eventually catch up with Britain's level of productivity but with much lower production costs. Such a catch-up process has occurred repeatedly in the global textile competition. This is precisely what the Korean textile industry did to the Japanese textile industry and, more recently, the Chinese textile industry to the Korean textile industry. This suggests that the competitiveness of the industry in its traditional mass-produced cotton fabrics could not have been retained in the long run even had the industry had changed its structure and technologies earlier.

This argument suggests that industrialised countries have to rejuvenate their mature industries as they cannot compete effectively when competition is based on cost. The strategy and process for de-maturity has to be examined carefully. As discussed earlier misreading trends and an inappropriate strategy were among the major factors which led to the collapse of the Lancashire cotton industry and Courtaulds. Examples can be drawn from other sectors. For instance, Firestone, once the major contender in the tyre market, could not recognise the long-term effect of the introduction of radial tires by Michelin in the 1960s on its competitiveness. The firm did not respond in a timely fashion manner which led to its long-term decline (Sull, 2000). It indicates that the emergence of new competitors that initiate new trends or encourage changes in market demand cannot be overlooked. Firms in developed countries have to continuously move-up the value chain to offer added value to their customers at a pace where they can avoid being caught-up by the lower-cost competitors or imitators. Therefore, it is crucial for firms to create the foundations for continuous change. This can only be achieved if they are receptive to change; implement a flexible strategy to accommodate different business environments; adopt flexible production systems and organisational structure.

3.7 Conclusion

This chapter illustrates how a mature industry and a large firm can fall into the maturity-trap. The historical context of the Lancashire cotton industry and Courtaulds shows that the maturity-trap is a consequence of organisational value and practices that have been accumulated for a long-period of time and have helped the industry and the firm to gain a competitive advantage. As the value and practices become deeply ingrained within the organisation, ironically, they become the barriers to change. Government policy was ineffective in its capacity to fundamentally change the industry as it only addressed one aspect (capacity reduction). Initiatives led by both government and the private sector were unable to strategically redirect the industry. Although the industry finally changed its structure, the response came too late. It found itself in the wrong position as the market changed and went in a different direction. The maturity-trap is a 'product' of structural, institutional and managerial (or entrepreneurial) failure.

Despite the common suggestion that the decline of the Lancashire cotton industry was irreversible, studies of the industry at the firm level found that a number of firms survived the crisis which hit the industry in the 1930s and in the 1960s. What distinguished the surviving firms from the majority of the Lancashire firms was their dynamic capabilities. These enabled them to escape the maturity-trap. Instead of being caught up in the cost-cutting strategy and the wave of mergers and acquisitions, they focused on the creation of new competencies and restructuring to tap into newly emerging markets. They became producers of specialist products where demand was determined by performance than low-costs.

In hindsight, it could be construed that the process of transition to be a specialist in the performance fabric market parallels the process towards specialisation in the low-cost cotton market in the 19th century. Likewise the process towards specialisation in the mid 19th century, the specialisation in the 1960s was driven by access to emerging markets, rapid adoption of the latest technology and reorganisation. It is indeed the contention of Abernathy's *et al.* (1983) that to understand the process of de-maturity, an industry should learn from the very process from which they gained their competitiveness in the first place. Thus, in a changed competitive environment after the First World War, the industry should have learned from its past and applied it to the new environment. Had they managed to transfer their capabilities to capitalise the emerging market as they did in the mid 19th century, the future of the industry could have been different.

3.8 References

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4

Technological Change in the Textile Industry: The Role of New Materials

4.1 Introduction

The development of the textile industry has been profoundly influenced by changes in the technology associated with the industry. There are three distinct technological fields that have changed the industry over the past two centuries. The first is the advancement of textile engineering which has helped the industry to gain high productivity, quality and flexibility. Technological innovation in this field has improved the speed of production by over 2000 times between 1750-2000 (OECD, 2004) which fostered the transformation of the industry from a cottage to a manufacturing industry. A number of different methods of spinning (dry-spinning, melt-spinning and electrospinning), weaving (jacquard weaving and 3D weaving), knitting (flat knitting and circular knitting) and finishing have significantly improved the quality of textile products and enabled the production of a wide range of textile products. Advanced textile machinery has reduced the use of water and solvents thereby decreasing the environmental impact of the production process.

The second is material science and engineering. The advancement of synthetic polymers, for instance, has revolutionised the industry from solely processing natural fibres to include a diverse range of polymers and composite materials. Synthetic materials are not only used for fibres but also for reinforcement and finishing materials. This technology has facilitated the development of new products for various applications that can not be achieved through processing natural fibres from apparel to aerospace and medical textiles. The emergence of a new textile subsector, the technical textiles[1], was fostered by advances in this domain.

The third domain is the development of information technology (IT) which has improved the speed and flexibility of production and delivery, and helped to achieve cost savings. The technology has enhanced logistical systems of manufacturers and retailers significantly as it enables 'real-time' communication between retailers and manufacturers to allow efficient real time order and delivery systems. The technology permits firms to maintain their inventory at the minimum level which has a significant impact on overall costs. It has fostered the development of 'fast fashion', a new business model in the fashion industry pioneered by Zara which has allowed retailers to bring down the delivery time of new collections from three months to two weeks at affordable prices. The technology has also facilitated the off-shoring practice which allows European retailers to manufacture their products abroad.

The first two technological fields have influenced the development of processing technology and fostered the fragmentation of market while the latest has radically changed the relationship among the stakeholders within the supply chain. Sewing is the only production stage where technological development is relatively stagnant. A number of attempts to automate the sewing process to reduce the utilisation of labour failed to materialise. For instance, research programmes conducted in Europe (1987-1991) under the Basic Research in Industrial Technologies for Europe (BRITE) and in Japan (1982-1990) under the Automated Sewing System were abandoned as the high level of investment hindered the commercialisation of the technology (Jones, 2006). While spinning, weaving and finishing have become highly capital intensive and use high technology, sewing remains labour intensive. This part of the production process has largely been transferred to low-cost countries.

The development of textile engineering and materials is interdependent as the processing of different materials often requires different equipment and methods to produce products with certain properties (Antonelli, *et al.*, 1990). As an illustration,

[1] Technical textile is defined as "textile materials and products intended for end-uses other than non-protective clothing, household furnishing and floorcoverings where the fabric or fibrous component is selected principally but not exclusively for its performance and properties as opposed to its aesthetic or decorative characteristics" (Textile Terms and Definition, The Textile Institute, Manchester, 10th Ed).

the introduction of synthetic fibres facilitated the 'diffusion' of open rotor spinning and shuttle-less looms between the 1950s-1970s as the superiority of the physical properties of synthetic fibres compared to the natural ones –such as increased elongation at break and toughness – allowed for the utilisation of high speed and high throughput machines. Economies of scale were relatively easy to achieve with this set up. In a similar fashion, the diffusion of synthetic fibres into textile products was fostered by the development of new processing equipment such as wet spinning, melt spinning and electrospinning which allowed textile firms to convert the fibres into products.

The advancement of synthetic materials (and the associated processing technologies) is very important for the textile industry in the developed countries as it has encouraged the growth of the technical textile sector. In contrast to the mature traditional textile market, the technical textile market has enjoyed an annual growth rate of approximately 4 per cent since 1995 (Figure 4-1). One of the fundamental differences between the traditional clothing and technical textile markets is their performance characteristics. While the former mainly offers fashionable design, fit and comfort the latter emphasises mechanical performance (such as strength, elasticity and toughness) and functionality that include ballistic resistance, flame retardancy, conductivity and being water proof. The requirements for the traditional market can mainly be delivered with the use of natural fibres whose technological advancement has reached maturity. Consequently, those who continue to use only natural raw materials for their products are much more vulnerable to competitive threats from low-cost countries as they do not have any form of technological advantage per se. Some firms have targeted the high-end segment of the market to avoid competition based on costs and compete on design and quality. Italy is the leader in this market. On the contrary, performance requirements in technical textiles can mainly be achieved through the exploitation of the different properties of synthetic materials or with a combination of natural and synthetic materials. It is reported that the share of synthetic fibres in the technical textile sector was 79 per cent in 2006 and this will increase to 81 per cent by 2010. Synthetic polymer and materials technology has advanced rapidly in that the 21st century has been recognised as the era of the 'advanced materials revolution' (Moskowitz, 2009).

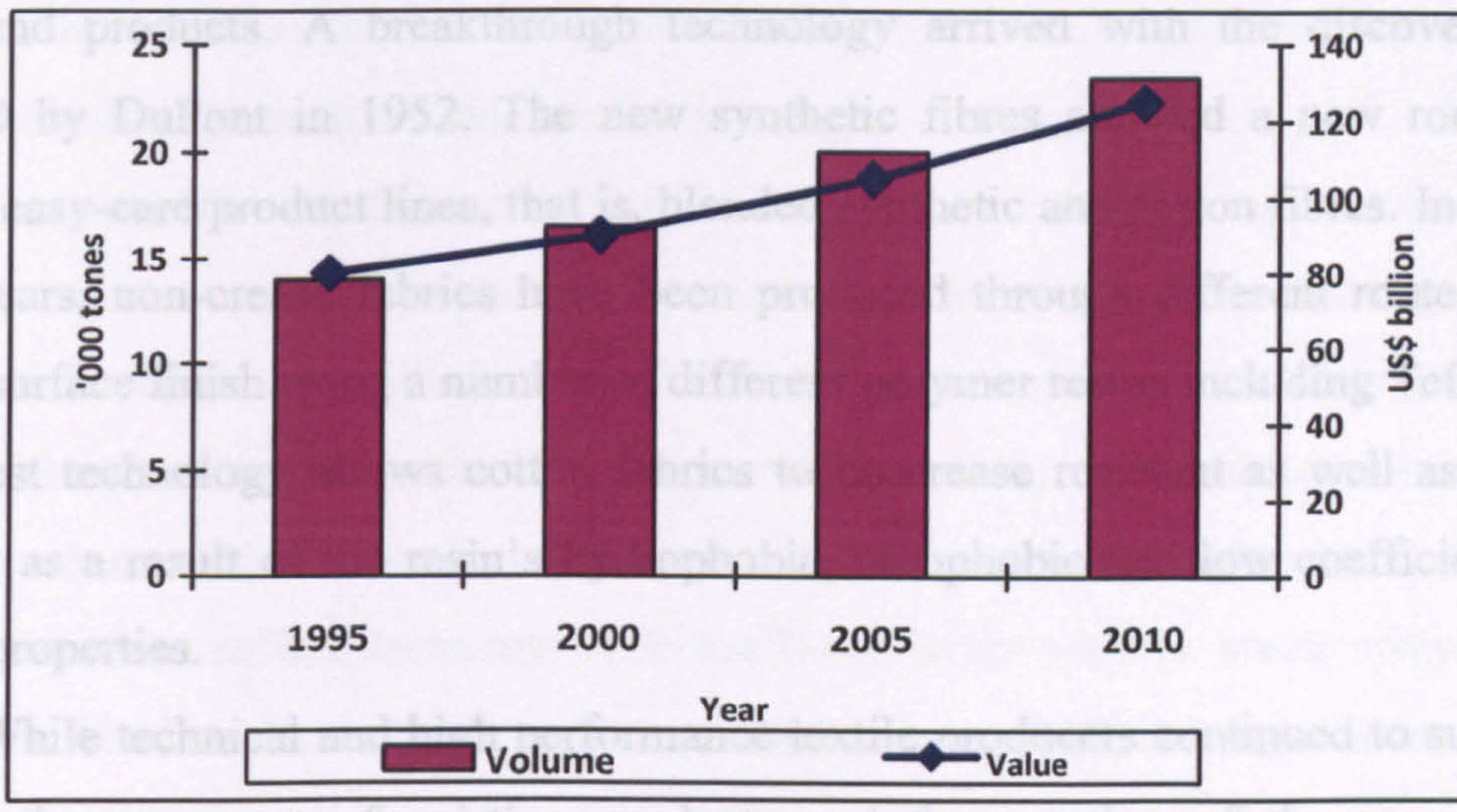


Figure 4-1. World-end use consumption of technical textiles, 1995-2010, in volume and value terms

Source: David Rigby Associates (www.davidrigbyassociates.co.uk)

Textile firms who shift their activities from the traditional market to the technical and the high-performance textile market have at their disposal various technologies that can be exploited. They have the advantage to change the basis of competition from lower costs to technological capability and product performance. In other words, the adoption of polymer and advanced material technologies can help the industry to bypass the maturity-trap and initiate the process of de-maturity. This, however, is only possible if firms can exploit the materials properties for use in commercial products.

The market for technical textiles is not confined to industrial applications. There are a number of traditional textile markets which have been revolutionised through the exploitation of synthetic materials. Firms which aspire to exploit their synthetic polymer capabilities to serve the traditional textile market have channelled their research efforts to mimic or exceed the properties of natural fibres through the manipulation of synthetic fibres. This offers added value to customers and permits competition with natural fibres. As an illustration, the demand for crease-resistant cotton fabrics has been around for nearly a century. Innovations to treat cotton fibres to produce non-wrinkle cotton fabrics have been continuously launched on the market since the 1920s. The UK-based Tootal Broadhurst Lee developed the earliest solution for the problem with formaldehyde-treated cotton. The use of this method raised a number of health and safety concerns, not to mention the poor performance of the end products. A breakthrough technology arrived with the discovery of Dacron® by DuPont in 1952. The new synthetic fibres allowed a new route to produce easy-care product lines, that is, blended synthetic and cotton fibres. In more recent years, non-crease fabrics have been produced through different routes that include surface finish using a number of different polymer resins including Teflon®. This latest technology allows cotton fabrics to be crease resistant as well as stain repellent as a result of the resin's hydrophobic, oleophobic and low coefficient of friction properties.

While technical and high performance textile producers continued to survive with the improvement of existing products and the creation of the new ones, traditional textile producers in Europe have been under constant pressure to reduce costs. The strategy of the Italian firms to avoid price competition through competition in design, quality and flexibility which was extremely successful between 1970-2000 appears to run its course. The luxury textile market has come under increasing pressures to reduce costs. Not only have China and India improved their abilities to produce high-quality textile products at lower costs, but, more importantly, customers' preferences have changed from high quality, higher priced products to fashionable products at more affordable prices.

On the other hand, Germany, whose strategic choice was to compete on technological competence, has greater opportunities to grow in the long run than Italy. Driven by rapid developments in materials science and engineering the German textile industry has vastly diversified their market and technology and continue to do so. This has made them less vulnerable to changes in external conditions. Italy, although highly diversified, is overly focused on the traditional textile market. The history of the world's textile industry has shown that this sector is much more vulnerable to cost competition.

The experience of the Italian and German textile industry shows that the early strategic choice on which the competitiveness of the industry was built has long-term consequences or is path-dependent (Arthur, 1989). As Germany's strategy appears to be more sustainable, the EU textile industry should channel its innovation towards the creation and the improvement of products that can only be achieved with the technological capabilities where Europe is competitive. However, for countries whose textile industries remain concentrated on the traditional textile market, a shift to technical and high performance textiles is a major challenge.

Certainly, the experience of the German textile industry could be a useful example to follow. However, today's business environment is very different from that when the German textile industry built up its competitive capabilities. Rapid changes in technology and market, tougher competition, expensive technological development and shorter product life cycle make it extremely difficult for textile firms to initiate a radical transition. The challenge is not only to break away from their established technological and organisational capabilities. As discussed in Chapter 2, deeply entrenched culture and practices, large infrastructure and established skills are difficult to change and have caused traditional firms to fall victim to the maturity-trap.

The objective of this chapter is to show that the textile industry is highly dynamic. Firms are exposed to a range of technologies to be exploited and opportunities to create new markets. However, it is the firm's individual strategy and innovative capability that determines whether to adopt or to ignore the new technologies and the paths to commercialise them. This chapter will show that this is influenced by the unique characteristics of individual countries and government policy.

4.2 The Origins of Synthetic Fibres and Recent Developments

Synthetic fibres or filaments are derived from synthetic polymers which mostly undergo an extrusion process. Polymers are defined as "*substances composed of molecules which have long sequence of one or more species of atoms or groups of atoms linked to each other by primary, usually covalent, bonds*" (Young and Lovell, 1991 , p. 3). Synthetic polymers are different from natural ones by the process of their creation. Natural polymers are available in nature (such as from wood and starch) whereas the synthetic ones are synthesised through the process of polymerization. Whereas the manipulation of the properties of the former is rather limited as they are provided by nature, the latter can be used to develop materials with customised properties. Synthetic polymers can be synthesised to form different structures -through the attachment of potentially reactive substances/molecules- and to possess different molecular weights –through the multiplication of given subunits (the 'monomers') to produce materials with various combinations of properties. This has made synthetic polymers attractive to industries as they can be exploited to develop a vast range of products for particular applications. For instance, the structure of aromatic polyamide (or widely known as Kevlar®) is formed by the multiplication of amide units which are bonded together by many inter-chain bonds. The structure permits high strength to weight ratio resulting in materials that are seven times stronger than steel (on a weight equal basis) and are very stable at high temperatures. The properties are suitable for diverse applications including body armour, cut-resistant jackets, protective gear for motorcyclists and building construction materials. Other properties can be delivered through the synthesis of different polymeric structures and molecular weights that include soft or rubbery, permeable or impermeable, conductive or isolating, transparent or opaque, long-term stable or biodegradable.

This development has opened up an entirely new pathway for the development of materials which has revolutionised markets across industries. For instance, a number of metallic components in automobiles and aircraft have been replaced with synthetic materials which offer better performance, lighter weight and often at lower cost. In another instance, the technology has fostered the creation of new products of various shapes that include disposable cutleries and artificial grass. As the molecular structure and weight is central to the major advantage of this technology (to facilitate the development of products with tailored properties) a rigorous understanding in the control of the molecular structure and the associated properties has become the main goal of research in the field. New understanding permits firms to select the most appropriate properties for particular applications and develop suitable processing methods.

The first scientist who promoted the fundamental understanding of polymers (or macromolecules) was Hermann Staudinger of ETH Zurich. In 1920 he discovered that the size of molecules was limitless as they could be replicated to form long chains. His concept, widely known as polymerization, was tested by Wallace H. Carothers at DuPont's laboratory. Carothers' work was a breakthrough which has radically changed the textile industry. Following seven years of experimentation to synthesise polymers, he discovered polyamide fibres, otherwise known as Nylon 6.6 in 1935 (Hounshell and Smith, 1988). In contrast to rayon, its predecessor whose long chain polymer is available in nature, nylon was made through chemical reactions to synthesize a chain made up of many monomers (polymers) from fossil fuels. Two of the most common versions of polyamide fibre are fibre 6.6 discovered by DuPont and fibre 6 by IG Farben. The latter was a German chemical firm which made attempts to reproduce the properties of fibre 6.6 without breaching DuPont's patent

The properties of the new fibres which have similarities with silk but are stronger and have better resistance to abrasion made the new fibre a perfect *substitution for silk imports.* The women's hosiery market was an attractive market as it consumed 80 per cent of the US silk market before World War II. However, it took the firm five years of development before the fashionable nylon stockings were finally launched on the US market in 1940. The delay in the commercialisation of the fibres was partly caused by the scaling up of production to commercial levels and problems with finishing (dyeing and printing). Indeed, the inferior dyeability of synthetic fibres compared to that of natural fibres has long been an issue and been subject to considerable R&D. Less than two years proceeding the launch, nylon had captured more than 30 per cent of the silk stocking market. During World War II, nylon production capacity was channelled into military uses such as tents, parachutes, airplane tire cords and glider tow ropes. This war-related consumption facilitated the creation of technical textiles for civil applications such as tents, extreme-weather and outdoor clothing.

Meanwhile, a dormant patent of DuPont turned out to be one of the most important inventions in the history of fibres in the hands of J.R Whinfield, a British scientist, together with his colleagues at the British Calico Printer's Association (CPA). They discovered another type of synthetic polymer, *polyester,* in 1941. Due to its various properties; cost-effective, durable and pleat resistant with aesthetic appeal, polyester became highly attractive to the textile industry. More importantly, its ability to be spun together with natural staple-fibres such as cotton and wool allowed for the production of less expensive and more durable (moth resistant) cotton and wool fabrics. In addition to apparel markets, polyester successfully made inroads into technical applications such as beverage bottles, high-quality packaging, videotapes and X-ray films. Today, polyester has the largest market share of the synthetic fibre market (77 percent). In the global fibre market, polyester has 40 per cent market share, surpassing that of cotton and other fibres since the mid-1990s.

The subsequent development of the synthetic fibres was fostered by a greater understanding of the relationship between the molecular structure of polymers and their physical properties. This knowledge opened up new windows of opportunity to develop polymers with superior properties such as ultra light and high strength fibres. Unlike the development of the first generation of synthetic fibres which aimed at the imitation of natural fibres (nylon and polyester to copy silk or acrylic to imitate wool), the next generation of synthetic fibres has been driven by demand for high performance fibres in different fields such as aerospace and the military. One of these achievements is the discovery of aromatic polyamides (aramids) family by DuPont in the 1960s. Included in this family is Nomex® -a heat resistant and strong synthetic fibre- and Kevlar® - high-performance fibres that exhibit superior properties to that of steel being several times stronger with a comparable elongation, lower density and high stability at high temperatures. Kevlar has a higher breaking tenacity than industrial nylon and polyester. Meanwhile, a Dutch firm, DSM, discovered ultra-high molecular-weight polyethylene fibres called Dyneema®. This fibre exhibits the highest tensile strength (15 times stronger than quality steel and 40 per cent stronger than aramid fibres, both on weight for weight basis) of any thermoplastics currently produced. These high performance fibres have facilitated the creation of numerous new applications through the exploitation of these fibres' properties. Automotive fabrics, spacecraft and aircraft fabrics, soft and hard armour, and reinforcements for tyres and mechanical rubber goods are just a few examples. In the clothing market, the fibres have made possible the creation of high performance, lightweight and comfortable protective clothing that include spacesuits, vehicle and body armour and anti-ballistic clothing. In contrast to the first generation of synthetic fibres which entered the textile market through consumer products, the market for high performance fibres has been limited to niche, high value-added and specialty products because of high production costs and their superior properties.

By the early1980s the majority of different synthetic fibres had been discovered and an immense range of products had been developed. The timeline of the initial commercialisation of synthetic fibre is shown in Figure 4-2. The majority of them are classified within the second generation of materials (Figure 4-3). As the processing technology of synthetic fibres and fabrics was capital intensive, firms made attempts to expand the application of the fibres into a diverse range of products –a generic technology- so that economies of scale could be achieved. Two possible routes were the development of new building blocks of polymer structure and the combination of two or more different materials to generate new or improved materials properties. While the progress of the former appears to have been slow, the latter advanced rapidly. The materials produced through this avenue are called composite, that is, materials made up of (at least) two individual materials. One component imparts its special physical properties to the other component and the matrix. The synergies of such combinations produce materials with properties that cannot be achieved from the individual constituents. Since its introduction in 1941 this avenue has opened up new development trajectories in materials science and engineering. Research can choose the optimum combination from a wide variety of natural and synthetic materials for specific applications. This route has fostered the development of emerging synthetic materials technology such as tailored smart, multi-functional and biodegradable materials. The new development may lead us to the next generation of synthetic fibres and composites (O'Brien and Aneja, 1999).

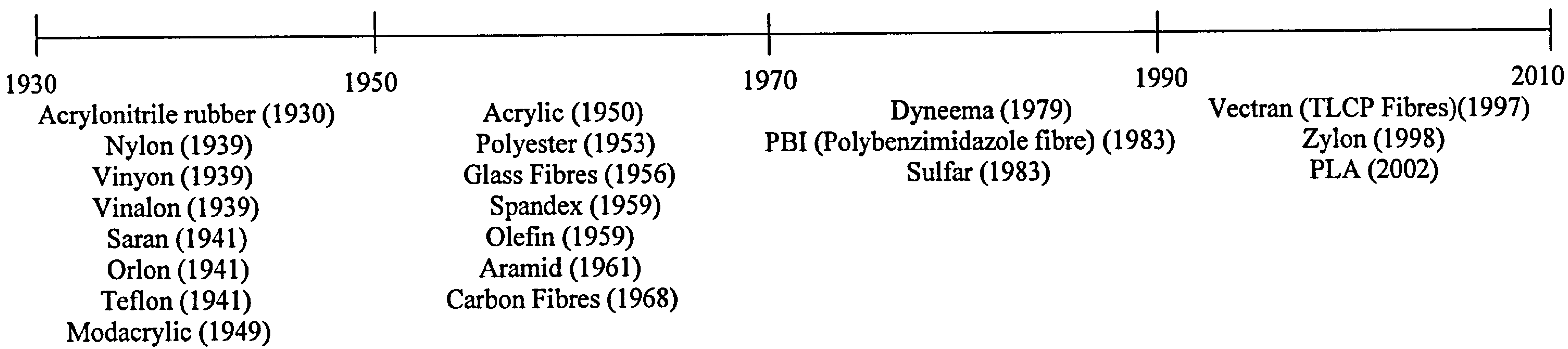


Figure 4-2. The timeline of the commercialisation of synthetic fibres
Source: Adapted from Warshall (1997)

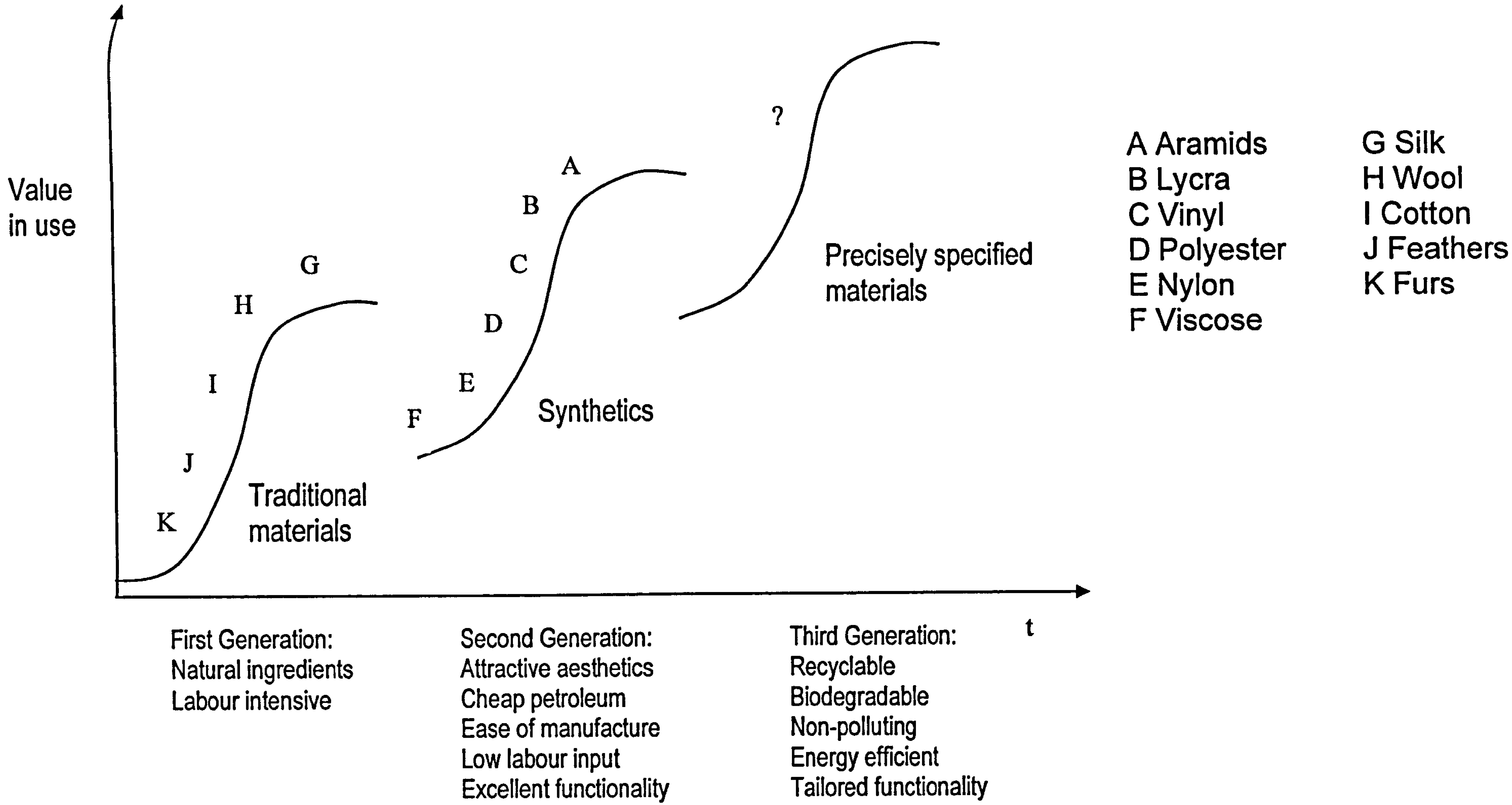


Figure 4-3. Three generations of materials development
Source: O'Brien and Aneja (1999), p. 2

Indeed, advanced composites are expected to play a fundamental role to fulfil demands in the 21st century (Hongu and Phillips, 1997). A vast range of composites have been developed from different combinations of fibres and matrices today to provide new solutions. The resulting properties range from greater impact resistance, biodegradable and fully recyclable to conductive and colour changing. Composites have also facilitated the development of fibres with multiple properties and functionalities. For instance, the reinforcement of cellulose –such as jute and flax- in biodegradable polymers has been developed to produce biodegradable plastics for the replacement of various plastic products. The application of biodegradable composites in textiles would foster significant reduction of textile waste. Biodegradable polymers such as polylactic acid (PLA) have been investigated so it can be used in a wide range of medical applications such as drug delivery and tissue scaffolds. Carbon fibre composites, despite invented and first used in the aerospace industry in the early 1960s, have recently found a new period of growth. As an illustration, twenty years ago, aircraft only contained no more than three per cent (in terms of weight) of carbon composites. The latest Airbus 380 contains 25 per cent while the Boeing 787 60 per cent (Scoltock, 2006). The value of carbon fibre production reached over €600 million in 2008, one fifth of which was dominated by the aircraft industry (Marsh, 2009). Demand in this market may increase by 500 times in the coming decades driven by environmental issues to reduce fuel consumption (Lewis, 2007). Britain will provide over €20 million in technology development to encourage the adoption of carbon fibre composites by user industries (Marsh, 2009).

Micro and Nano-Sized Fibres

A new innovative spinning technique – a combination of melt-blown and flash spinning - invented by Toray Industries (Japan) in the 1970s fostered the development of synthetic microfibers. Microfibres are defined as fibres of less than 1 decitex (=0.9 denier)[2] or at least 60 times finer than human hair (McIntyre, 2003). Microfibre is a radical innovation in fibre engineering as it facilitates the development of fibres whose properties are very similar to those of silk, that is, the

[2] One denier is defined as the weight of a filament of 9000 meters in length and was used to designate the coarseness of filaments of raw silk or nylon (Hongu and Phillips, 1997) p. 3

soft feel, drapability and have a luxurious appearance. The novel property of fabrics made with these synthetic microfibres is its inherent breathability -a property which could not be achieved through synthetic fibres with larger dimensions. This new development is a major breakthrough in fibre engineering towards mimicking the properties of natural fibres

The properties of microfibres have made it a very popular alternative to cotton apparel for sports wear. In contrast to cotton fibres which absorb sweat and cause fabrics to become damp and have a sticky feel on users' skin microfibers transfer body moisture to the fabric surface through capillary action that helps with rapid evaporation because of the larger surface area. This wicking property keeps the users cool and dry. Microfibre yarns can also be tightly woven to form water repellent, windproof and yet breathable fabrics. These properties and functionalities made the fabrics suitable for outdoor apparel. Microfibres have gained in popularity for industrial and household cleaning applications because of their high water absorbency and ability to clean up dirt. The application of microfibre nonwoven fabrics in the medical textile market extends from medical apparel to wound dressings. The fibres have also been used intensively for nonwoven filters. These examples show that the ability to control the physical properties of fibres can be exploited to produce a variety of products for a wide range of applications.

Further advancement in spinning technologies has fostered the development of nanofibres, fibres with diameters between 1-100 nm. Materials with nanometre features possess large surface areas per unit volume which has an impact on the dramatic increase of their surface energy (Siegel, 1999)[3]. This phenomenon has resulted in a significant increase of surface reactivity to their environment which might illustrate why materials at the nanometre scale have different chemical and physical properties compared to bulk materials (Cao, 2004). For instance, crystals at the nanometre scale have a low melting point –the difference can reach as large as 1000^{0}C - as the high energy of the surface reduces the materials' thermal stability. In another instance, silver nanoparticles have antimicrobial properties whereas its bulk materials do not have such properties.

The ability to control materials at this scale can open up new opportunities for the modification of fundamental properties of materials and for the construction

[3] This phenomenon is measured as the ratio of surface area to volume.

of new structures to produce entirely new materials. At present, research is underway to improve the understanding of the phenomena of materials at the nano scale. For instance, as the high surface reactivity of nanomaterials tends to cause agglomeration when they are embedded in a composite structure effective routes to gain uniform distribution of nanomaterials in matrices are being investigated. The agglomeration of nanomaterials in matrices potentially reduces the resulting performance of the composite materials due to the reduction of the overall surface energy (Cao, 2004). In another instance, an ability to control the orientation of nanomaterials with respect to the mechanical load applied is required to improve the reinforcing effect so that significant advantages from load transfer phenomenon can be achieved (Schulte and Nolte, 2005). This shows that without a comprehensive understanding of the phenomena at the nano scale, the control over the physical and mechanical properties of the materials cannot be achieved. This will hinder the exploitation of nanotechnology in general.

Nanofibres can be produced through a number of different methods that include melt-blowing, spun-bonding centrifuge spinning (jet) and electrospinning. The first two methods are relatively high throughput and economic but can only produce nanofibres at the order of ~500nm. Electrospinning[4], on the other hand, is able to form real nanometre-sized fibres (<100nm). Research is focused on investigating the properties of nanofibres from different materials, including nylon, carbon and carbon nanotubes. The filtration industry is expected to gain great advantages from electrospun nanofibres as they permit the filtration of very fine particles. Meanwhile, carbon nanofibre-reinforced composites are potential to be used for materials with high strength and stiffness properties. At extremely low addition of the filler (carbon nanofibres) the resulting materials exhibit significant improvement of strength and stiffness whilst maintaining the ductility and toughness (Schulte and Nolte, 2005). Such composites also have the potential to provide thermal and electrical conductivity (at a lower level).

The use of nanofibres in commercial products depends on the ability of firms to find applications that will generate returns for further improvements and

[4] Electrospinning is a spinning method initially invented in the 1930s. It is an electrostatic process that has been widely used for drawing out fibres from numerous polymers. It forms nanofibres using 20KV voltage differential along the polymer stream (solution or melt) (Laxminarayana and Jalili (2005).

developments. As argued by Rosenberg (1996) a new breakthrough technology comes to the market in a very primitive form and does not give any picture about the eventual applications. This uncertainty is a great challenge faced by firms in their investment strategy as they have to make assumptions about the future market of the technology on which their investment decisions are based. The poor investment strategy of Courtaulds in the carbon fibre market as discussed in Chapter 3 is a useful example. It is often that extended improvements are required to expand the practical application of a new technology. During this process complementary technologies that foster the practical application and wider diffusion of the technology may be found. The initial introduction of personal computers and the laser are useful examples (Rosenberg, 1996). The diffusion of the computer into wider economy was facilitated by the replacement of vacuum tubes by transistors which permitted the development of personal computers.

Although nanofibres exhibit superior properties than other existing fibres at greater dimensions, it is rather too early to predict the future market of the technology. Nevertheless, a number of market studies suggest these have an encouraging future (see for example Cientifica, 2006). The report suggests that the highest growth of the application of nanotechnology in the textile market will be generated from non-traditional sectors such as the military, sports textiles, medical textiles and aircraft where performance rather than cost alone is the main driver. Nevertheless, the adverse effects of the materials on health and the environment need be investigated more thoroughly (Mnyusiwalla, 2003). More importantly, the cost-performance factor will also have to be taken into consideration to foster the diffusion of nanotechnology in the textile market.

In brief, materials science and engineering is advancing rapidly. The close relationship between the technology and the textile industry which has built up since the development of the first synthetic fibres may significantly influence the future development of the high-performance textile market. This suggests that textile firms have at their disposal new technologies to be exploited. To capitalise from the development of materials science and engineering, firms have to be able to adopt the technologies and use them to develop competitive products. The following section examines the impact of the advancement of polymers on the textile industry.

4.3 Synthetic Polymers in the Textile Industry

The development of synthetic polymers was led by large chemical firms with DuPont as the global leader in the field. In Europe, ICI, DSM and IG Farben (it was demerged into AGFA, BASF, Bayer and Hoechst, its original constituents, in 1952) were the leaders although other chemical firms, including AkzoNobel, and Rhone-Poulenc played a significant played in the development of synthetic fibres.

Synthetic fibres are converted into textile products for various applications through a number of processing stages. Staple fibres are spun (filaments are twisted) into yarns and chemically treated before being transferred into the weaving, knitting or nonwoven department to form fabrics. Finishing processes including dyeing, printing, permanent press treatment and coating are applied to fabrics before they are sent to the converters, distributors, clothing makers or end users. This last stage of the textile production process has recently attracted more attention as a means to add functionalities to fibres or fabrics. Finishing technologies that permit the deployment of ultra-thin layers of functional materials on fabrics or fibres, for instance, is claimed to facilitate the production of functional fabrics without damaging the properties of the fibres. Various promising approaches in this field are currently being investigated such as plasma liquid (and gas) deposition and digital printing. Plasma technology has been modified so it can function within an atmospheric-pressure environment. Plasmatex was the early European project (1997-2000) to develop plasma technology for flexible substrates operated in the atmospheric pressure. Further progress on this front has been made by a number of textile firms in Europe, including the German firm, Freudenberg, which is planning to commercialise products modified by the technology in the near future. Other firms adopt digital printing to deposit functional materials on fabrics. The Dutch firm, Ten Cate, for instance acquired a digital printing developer, Xennia, to join the race in the development of multifunctional fabrics.

Radical Change in Textile Products

Prior to the discovery of synthetic fibres, the non-clothing textile products such as tents, tarpaulins and sailcloth had used natural fibres for centuries (Horrocks and Anand, 2000). However, due to the limited properties of the natural fibres and the lack of knowledge to manipulate them the range of applications of the fibres in technical applications was very narrow. Synthetic fibres, on the contrary, can be manipulated to meet tailored specifications which foster their broad applications. To exploit this technology for textile applications, textile firms have established new linkages with different sectors by which the diffusion of technical textile products into various sectors was encouraged. As a result of this, synthetic fibres and other synthetic materials have received growing recognition for their strategic role in the future of the European textile industry since the 1980s.

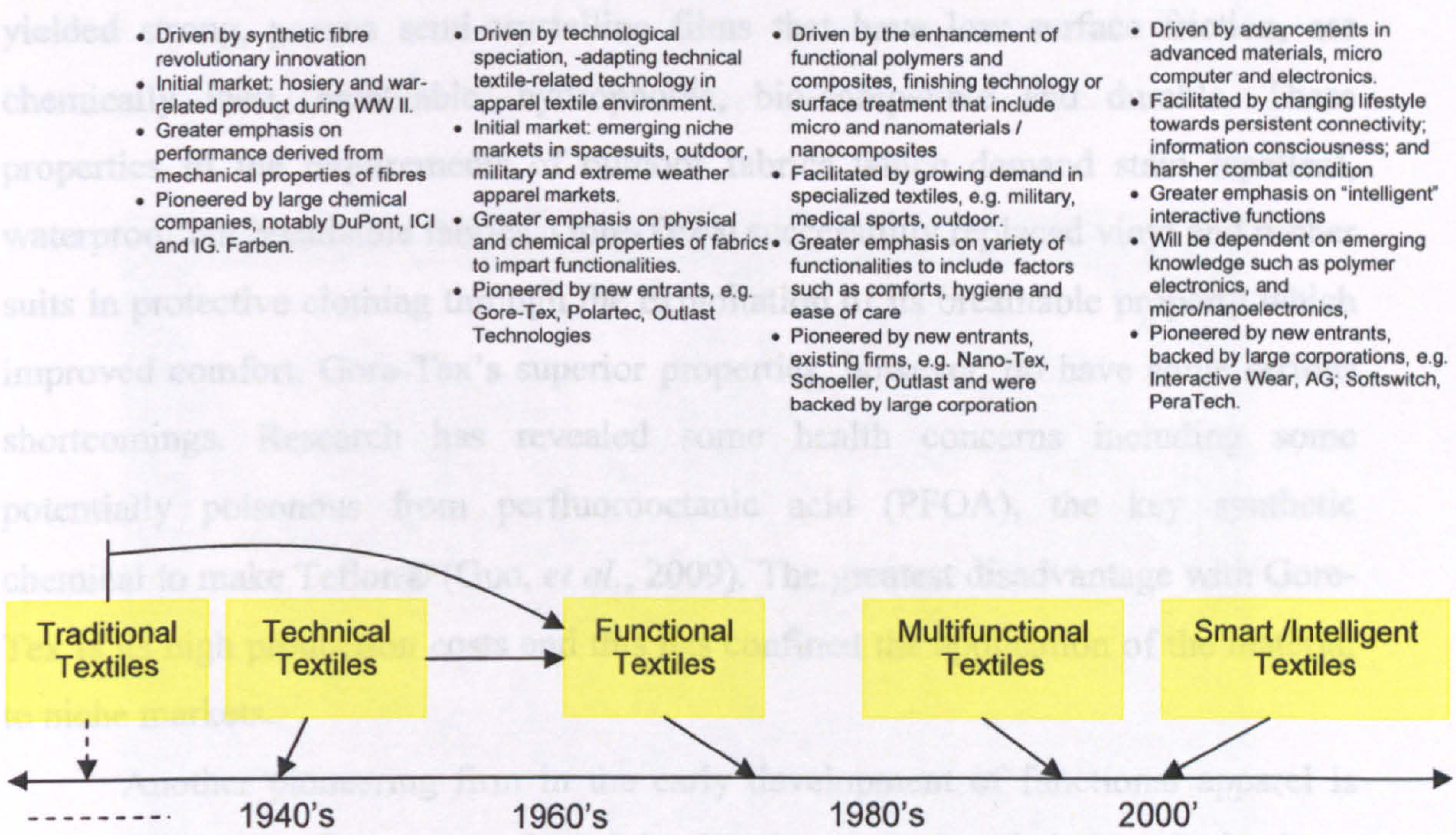


Figure 4-4. The evolution of product innovation in the textile industry
Source: Author

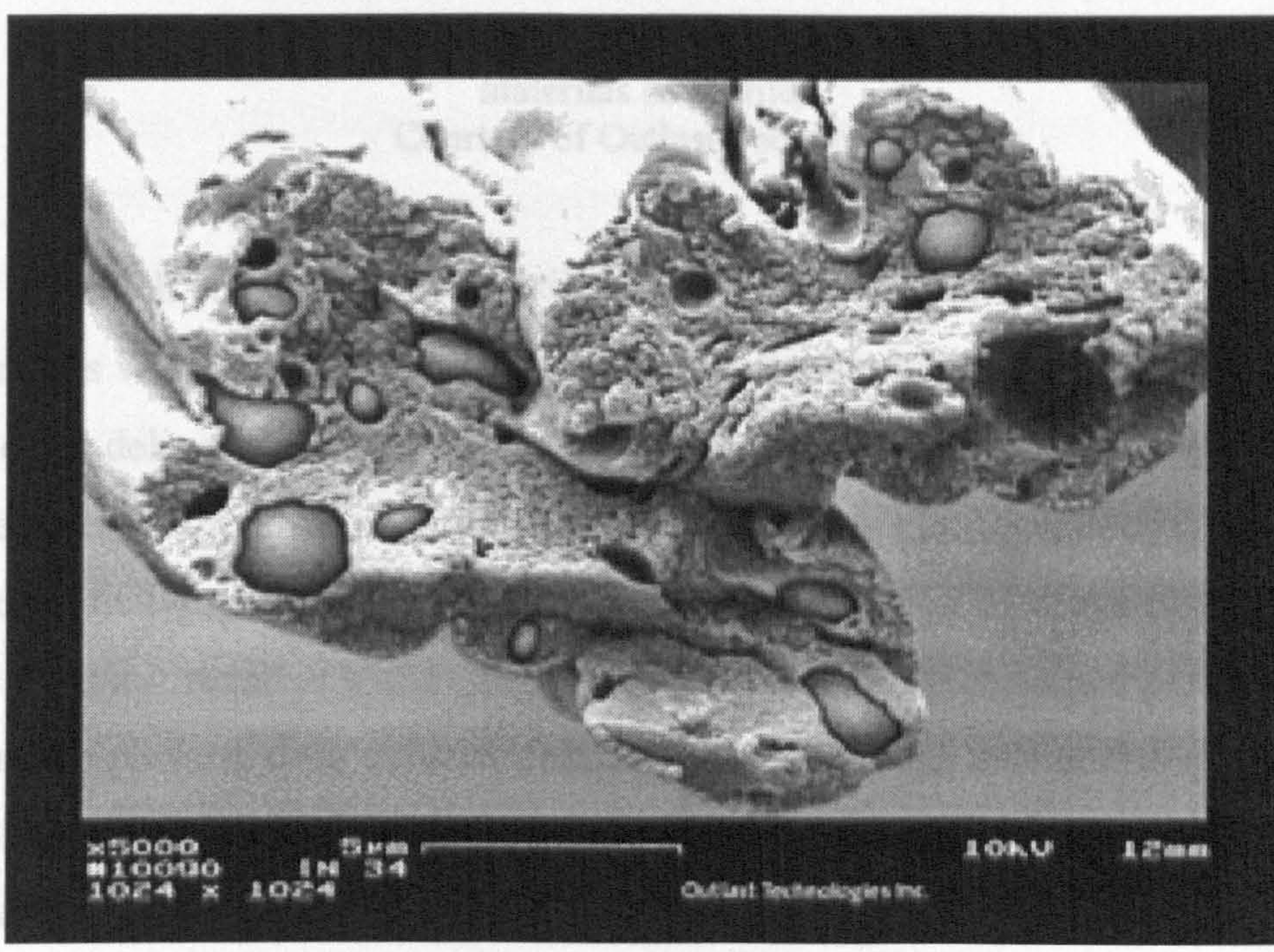
For analytical purposes, the evolutionary path of textile products can be divided into five stages, each of which has distinct characteristics[5] as illustrated in Figure 4-4. It can be seen that the evolution of product development parallels with (or is driven by) advancements in polymer science and technology and the changing nature of demand

[5] Here, reference is made to non-traditional textiles (technical, functional, multifunctional and smart textiles) as high-technology textiles unless otherwise specified.

Following the development of technical textiles which was fostered by the discovery of a series of synthetic fibres including polyamide, polyester, polypropylene, polyethylene, Teflon®, Nomex®, Kevlar® and Dyneema®, a number of innovative firms such as Gore-Tex and Malden Mills developed processing technologies to exploit the properties of synthetic polymers for functional apparel. Gore-Tex® is one of pioneering products of functional fabrics through the process of lamination of polymeric thin films on fabrics. This firm developed a new processing method (extrusion under stress through a faster take-up rate than extrusion rate) to alter the physical structure of Teflon® in 1969. The process yielded strong, porous semi-crystalline films that have low surface friction, are chemically inert, breathable, hydrophobic, bio-compatible and durable. These properties fit the requirements of outdoor fabrics which demand stain repellent, waterproof but breathable fabrics. Gore-Tex® successfully replaced vinyl and rubber suits in protective clothing through the exploitation of its breathable property which improved comfort. Gore-Tex's superior properties, however, do have some serious shortcomings. Research has revealed some health concerns including some potentially poisonous from perfluorooctanic acid (PFOA), the key synthetic chemical to make Teflon® (Guo, *et al.*, 2009). The greatest disadvantage with Gore-Tex is its high production costs and this has confined the application of the material to niche markets.

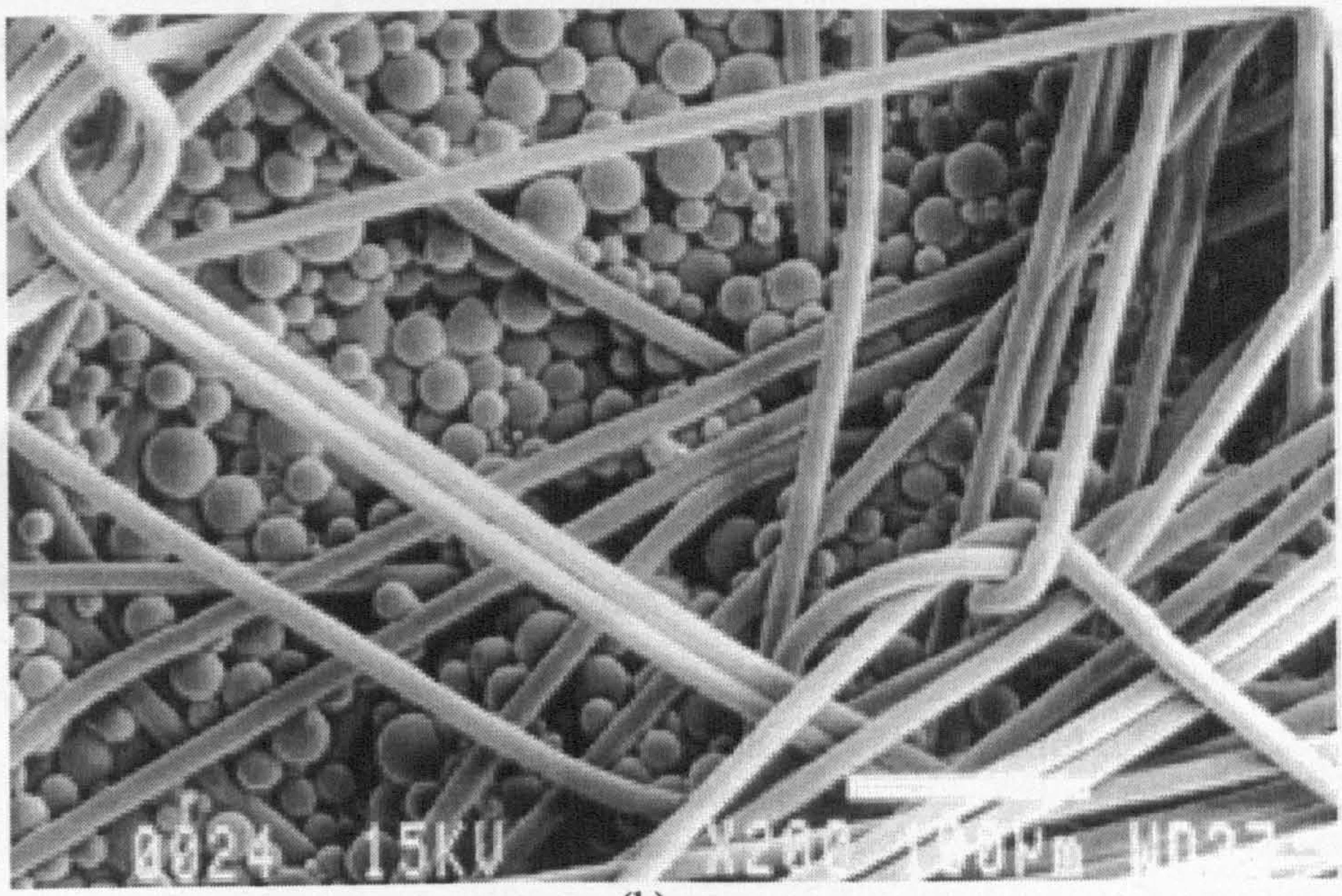
Another pioneering firm in the early development of functional apparel is Malden Mills. The firm was on the brink of bankruptcy when their fake fur business lost its consumer appeal in the late 1970s. Its last attempt to save the firm was to develop a modified polyester product called Polar Fleece, a mountain-climbing and hiking material that mimicked sheepskin in 1981. The production cost of the fleece was less than half of that of sheepskin with greater thermal insulation. Through a partnership with Patagonia, a French sportswear producer, Polar Fleece was successfully commercialised. Its brand name, Polartec, has become the generic name for synthetic fleeces.

A more recent development of functional and multifunctional textiles uses materials such as silver nanoparticles or titanium dioxide and substance-filled microcapsules to impart desirable features into fibres or fabrics. Silver nanoparticles can impart antibacterial properties while titanium dioxide exhibits self-cleaning characteristics. Phase-change materials (PCMs) are another interesting class of compounds made of temperature-regulating structures made of paraffinic substances protected within microspheric shells (Figure 4-5). The mechanism of phase-shifts (solid-liquid) is promised to be able to protect the wearers from changing temperature which often causes discomfort, hypothermia and fever[6]. Outlast Technologies developed Thermocules®, the pioneer in this field, from the knowledge it had built up from its involvement with a NASA project in 1988 before improving the technology to make it commercially viable for the main stream clothing markets. Outlast has applied its technology to some other apparel markets such as sports apparel (ski and snowboard apparel, ski boot and glove liners), bedding products (mattress pads, comforters and pillows) and jumpers.



(a)

[6] The phase-changing mechanism is triggered by changes in temperature because of climate conditions or the wearer's body temperature. The substances absorb the heat generated by the body of the wearers the temperature increases. During the process, the heat shifts the phase of the substance from solid to liquid. Conversely, the materials release the heat they previously absorb when the temperature decreases. The change shifts the substances back to solid. As a result, the wearers feel comforts despite the changing temperature.



(b)

Figure 4-5. (a) Outlast microcapsules in viscose fibres; (b) Outlast microcapsules as coating materials on textiles
Courtesy of Outlast Technologies, Inc.

Research in advanced textiles has attracted multidisciplinary research programmes which include biochemistry and biotechnology to foster the creation of novel drug delivery systems. Controlled drug release can specifically target the intended areas rather than randomly as is the case today (Textiles, 2005). Research in novel drug delivery aims at control over the concentration of drugs in the targeted tissues so that it remains within the therapeutic range for a sustained period of time. Materials to perform drug delivery functions either through subcutaneous (under the skin) or intramuscular (into a muscle) are often based on naturally occurring polymeric compounds including polyatic acid and glycolic acid. Microspheres made of such polymers can be filled with different kind of drugs to cure a range of diseases or deficiencies such as cancer, hormone deficiencies and addiction. An early-stage product of this technology that has been granted FDA approval is Ortho Evra, a skin patch for birth control as illustrated in Figure 4-6. However, controlled drug release requires a long-term R&D programme (Textiles, 2005). It requires smart functions comprising of sensors to measure the level of drugs in target tissues and actuators to activate the release of drugs. The sensors and actuators are linked in a closed smart system. One potential route for improvement is through the use of nanocapsules as significantly greater number of capsules incorporated into fibres may result in a great increase in the system's reactivity that may result in significantly improved performance.

Figure 4-6. Ortho Evra skin patch for birth control
Courtesy of Ortho Evra

The 2000s has signified the most recent trend in textile product development with the advent of smart fabrics and intelligent textiles (SFIT). The novel concept is emanating from multidisciplinary research efforts involving electronics, computing and communication technology, medicine, polymers and textile technology. This new research field investigates the potential of textiles to possess 'smart' functions, that is, they are responsive to changes in the environment including temperature, humidity, ultraviolet and blood pressure. To be 'smart', textile products must possess a number of different functions whose variations depend on individual applications as illustrated in Figure 4-7. Research has focused on the development of materials that can sense and react to changes in their direct environments and which can be integrated into fabrics to impart various functionalities. These materials include conductive polymers[7], light emitting polymers[8] and shape-memory polymers[9]. These materials open up new possible applications such as flexible electronic components (mainly for disposable electronics) and sensors. Semiconducting polymers have the potential to be applied to fabrics to make solar cells. Shape memory polymers can be spun into fibres and blended with other fibres to form yarns. Fabrics made from shape-memory polymers deform in response to a change in environment such as temperature or moisture levels.

[7] Polymers that are able to conduct electronic current.
[8] Polymers that can convert electricity into lights.
[9] Polymers that can transform themselves from temporary deformed shape back to their predefined shapes by changing the external environment (e.g. temperature and moisture level).

A number of electronic and communication firms including Philips and Motorola, and system integrators such as Softswitch (recently acquired by Peratech, a North Yorkshire-based technology firm), Eleksen and Interactive Wear, have been working with textile firms, fashion designers and brands to develop wearable electronics. The development targeted a number of functionalities such as communication and remote control devices, physio-monitoring devices, and power generators integrated in fabrics without sacrificing the fashionable and aesthetic aspects of the textiles or clothing. They have been successful in integrating sensor technology into garments to allow the wearers to control their electronic gadgets such as iPODs and digital cameras from a set of keypads on the sleeves. Sports brands such as O'Neill, Burton and Adidas have adopted the new development into their product lines.

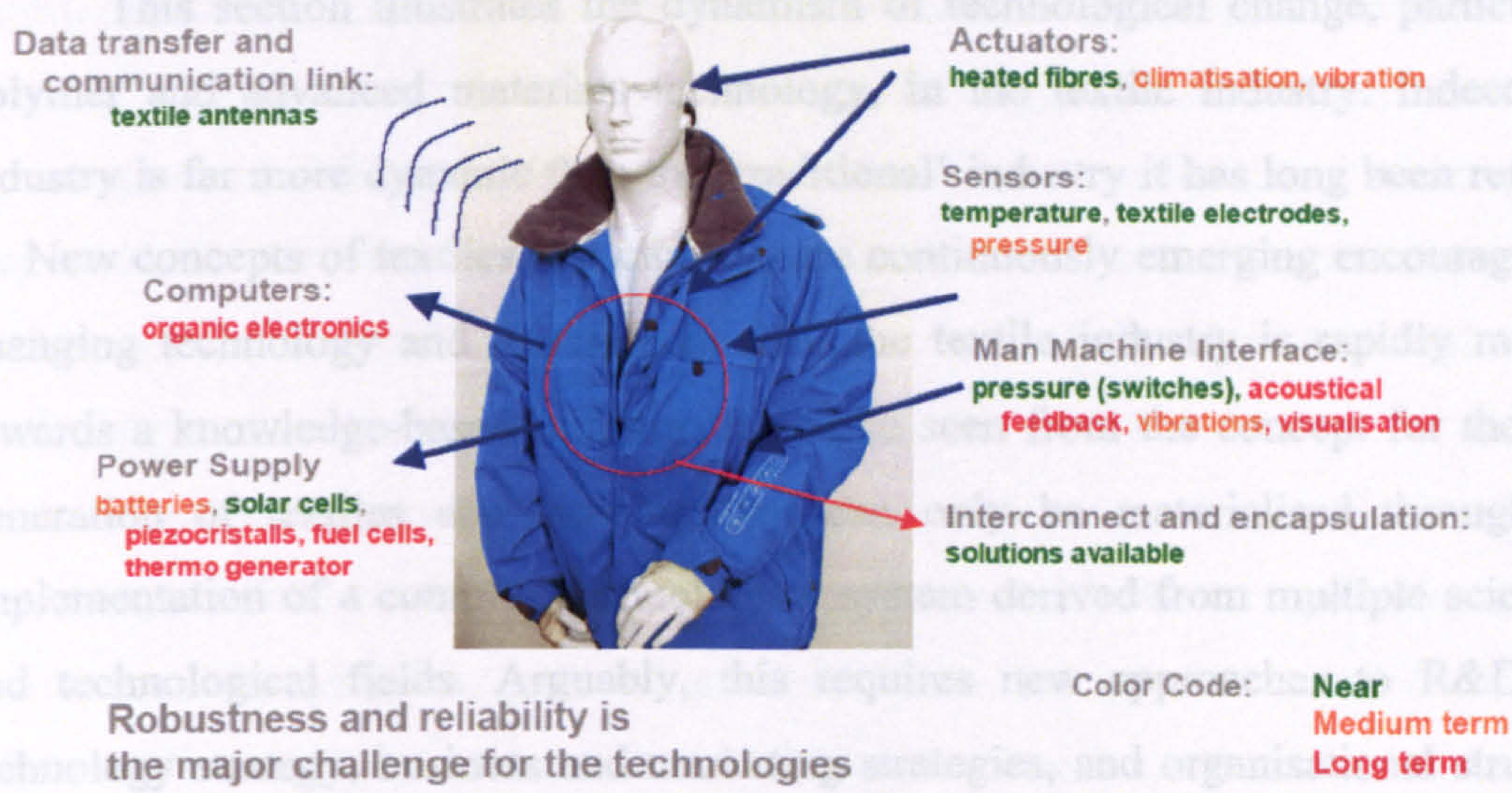


Figure 4-7. Application of smart textiles (e-textiles) in the short, medium, and long-term
Courtesy of Markus Strecker, Interactive Wear, AG

From left to right: ICD+ Jacket (2000); Motorola-Burton Snowboard (2006); Zegna iJacket (2007); Voltaic Backpack (2007)

Figure 4-8. The development of electronic textiles
Courtesy of Philips-Levi's, Audex, Zegna and Voltaic System

The future application of this emerging concept will involve a complex technological system. For instance, combat gear is envisioned to possess a communication system embedded into fibres or fabrics whereby injured soldiers can send messages to the nearest base. The communication system can also send signals to an integrated medication function, for example, antibiotics encapsulated in fibres, so that the injured troops can receive first aid treatment. To deliver such a smart function, a complex system comprises of sensors (to detect wounds) and actuators (to send signals to the necessary recipients) which are linked together with a certain mechanism of data transmission has to be embedded within the structure of the garment. For this particular application, multidisciplinary research in conductive polymers, microelectronics and computing, and biochemistry may play an important role.

This section illustrates the dynamism of technological change, particularly polymer and advanced materials technology, in the textile industry. Indeed, the industry is far more dynamic than the 'traditional' industry it has long been referred to. New concepts of textiles and clothing are continuously emerging encouraged by changing technology and demand. In fact, the textile industry is rapidly moving towards a knowledge-based industry. It can be seen from the concept for the next generation of textiles and clothing that can only be materialised through the implementation of a complex technological system derived from multiple scientific and technological fields. Arguably, this requires new approaches to R&D and technology strategy, business and marketing strategies, and organisational structure and routines. Traditional textile firms who wish to capitalise from the emerging technologies and markets will need to change their entire business strategies and paradigms. These issues will be highlighted in the case studies in Chapter 6 and 7.

Market Fragmentation and Industry Structure

The evolution of textile products over the past 60 years has been driven by continuous changes in the industry's technology and market demand. Technical textile markets are now highly fragmented with customers ranging from protective garments, sports and medical to armour, automotive and aerospace. The early demand for synthetic fibres to replace silk emerged as silk imports from Japan was interrupted because of Japan's invasion of Manchuria and subsequently the outbreak of World War II. This condition has facilitated the diffusion of synthetic fibres in various markets that previously used silk as the raw materials. The war fostered the emergence of new demand for synthetic fibres in the US as the use of natural resources was tightly controlled by the government. The fibres were used for war related consumption such as tents and parachutes which fostered the further development of synthetic fibres for technical textile applications.

In sports markets, demand for synthetic fibres was driven by the need to improve the performance of athletes of various sports. The success of microfibre polyester to displace the use of cotton fibres in sports jerseys because of its superiority to release moisture as discussed earlier is an example. In another example, the development of Spandex® by DuPont which offered lightweight, stretchy and water resistant properties replaced the use of the knitted jersey and cotton in swimming costumes. Spandex®'s lower surface friction has improved the speed of swimmers significantly. Meanwhile, the high cost of the maintenance of natural grass on different sports has ignited demand for synthetic turf. Although the first synthetic turf was used in the 1960s R&D is still underway to improve the performance of the turf for different sports as well as for domestic applications (including gardens and parks).

The global war on terror launched in 2001 caused a sudden surge of investment in R&D in fabrics for armour applications. Different types of polymers and composites and their processing methods are being investigated to produce lighter and more flexible fabrics for ballistic protection. A combination of ceramics and composites is also being developed by Ten Cate. Meanwhile, new government policies concerning environmental, health and safety issues have also created new demand in high performance textiles that includes improved fume filters, airbags, seatbelts and flame-proof interior fabrics.

The evolution of textile products has shown an increasing tendency for greater market fragmentation over time. Each application is tailored to meet the different needs through the manipulation of fibres or fabrics. As discussed earlier, such a development is underpinned by the advances in materials science and engineering that permits the development of tailored properties and functionalities, and by progress in fibre and textile engineering. It is apparent that the adoption of those technologies brings the textile industry closer to a knowledge-based industry.

A number of traditional textile firms have moved up the value chain to produce high value-added products derived from scientific research. Those firms have built up *new capabilities* in fibre processing, fabric forming and finishing as the prerequisites to compete in the technical and high performance fabric markets are very different from those required in the traditional market. However, an improved technical capability on its own is not sufficient to take advantage from the development of materials science and engineering. Firms will need to change every aspect of their business that includes R&D paradigm, product development and commercialisation, and their structure and routines. To illustrate this, textile firms will need to improve their technical capabilities to enable them to integrate new technologies into their existing systems and to use the technologies to develop competitive products. Nevertheless, as high-technology textiles requires a new set of knowledge and know-how such as advanced materials, microelectronics, biotechnology, biochemistry and which is very different from that in traditional textiles, traditional textile firms face great challenges to master the different technologies.

An alternative approach to build up new capabilities in multi-disciplinary fields is through networking with organisations and individuals who have expertise in the relevant fields. This is a less risky strategy to have access to different knowledge domains. Networks of alliances to exchange and generate new knowledge as argued by Chesbrough (2006) is more appropriate for the competitive environment of the 21st century characterised by the exponential rise of R&D costs, significantly shorter technological life cycles, abundant and distributed knowledge, multi-technological products and rapid technology and market change. Under these circumstances, incentives for relying entirely on a firm's own research and competencies are low as innovative ideas and competitive solutions can come from multiple sources. In fact, control of knowledge by a few large firms (DuPont, ICI and IG Farben) found during the early development of synthetic fibres between 1940s-1950s is no longer applicable today as knowledge has become increasingly distributed. Chesbrough argues that firms need to work together with other firms (suppliers, customers, competitors) or to acquire externally-generated technologies through either licensing or acquisitions to keep up with the new business environment.

This argument suggests that the diffusion of advanced materials will, if not already, affect the structure of the textile industry. New linkages with different sectors and different approaches to knowledge generation and commercialisation will certainly affect industrial organisation. This will lead to the reconfiguration of the supply chain and, eventually the reconfiguration of the textile industry as shown in Figure 4-9. Furthermore, if the emerging smart textile concept grows, the invasion of non-textile firms (such as electronics and pharmaceuticals) into the textile industry may advance the structural reconfiguration.

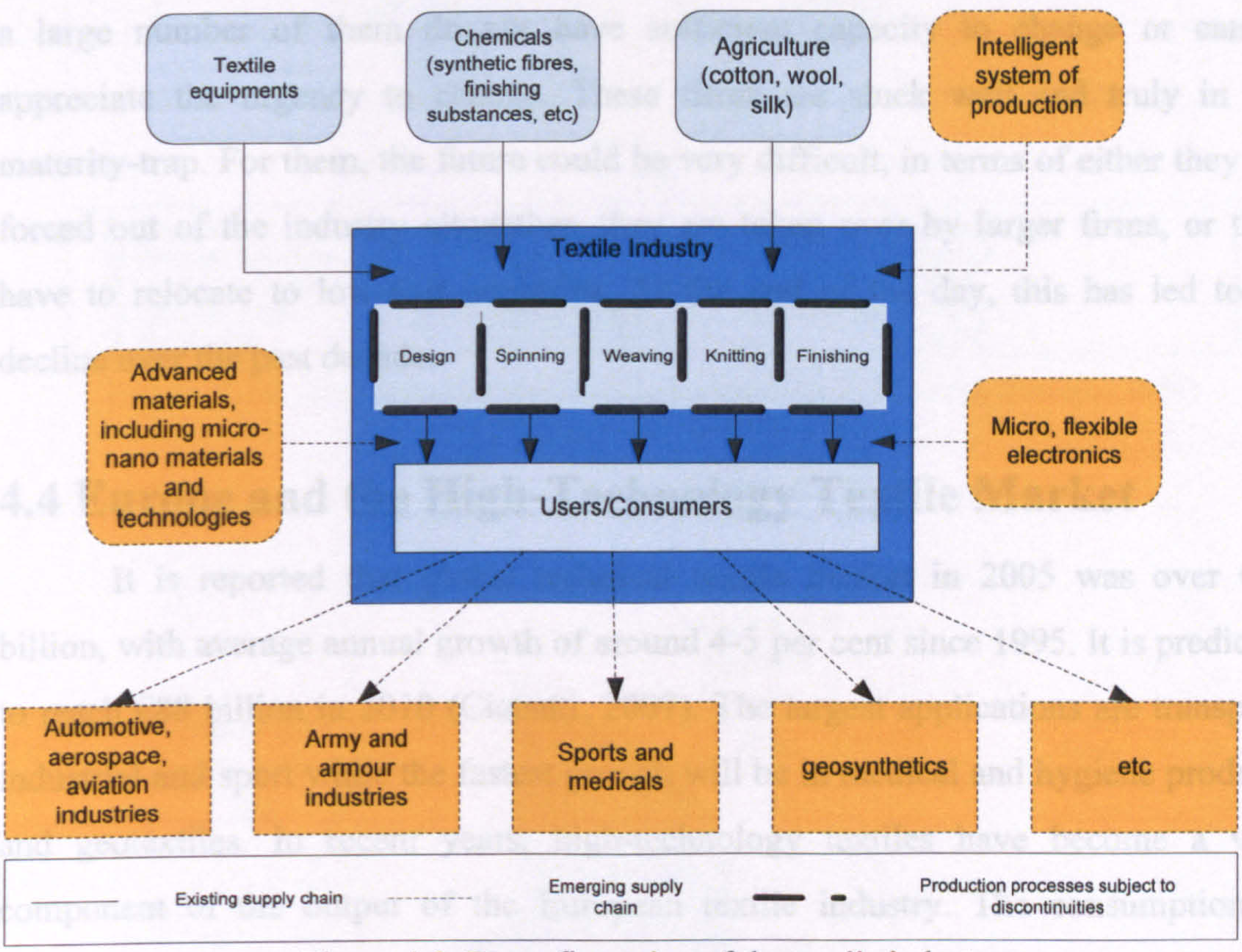


Figure 4-9. Reconfiguration of the textile industry
Source: Author

The textile industry is dynamic, a world away from one where technology is stagnant along with demand as it has been assumed (von Tunzelmann and Acha, 2006). The technology has constantly changed, the market has expanded substantially and increasingly fragmented and knowledge is now much more diversified. As discussed earlier, this condition has attracted the EU's attention to encourage change and turn the industry into a knowledge-based industry. This is the type of industry where Europe can maintain its competitive advantage over the long-term. The textile industry has the potential to be rejuvenated and escape from the maturity-trap.

This however relies on the ability of textile firms to anticipate future trends and to continuously adopt new technological developments to adapt to and, moreover, actively influence changes in technology and demand to their advantage. In other words, the role of textile entrepreneurs is central to take the textile industry forward. In Europe, the excessive market fragmentation (see Chapter 1) may impede or delay the rejuvenation of the industry. Firms who have been able to shift their textile competencies from traditional to high-technology textiles grow. Nevertheless, a large number of them do not have sufficient capacity to change or cannot appreciate the urgency to change. These firms are stuck well and truly in the maturity-trap. For them, the future could be very difficult, in terms of either they are forced out of the industry altogether, they are taken over by larger firms, or they have to relocate to low-cost countries. At the end of the day, this has led to its decline over the past decade.

4.4 Europe and the High-Technology Textile Market

It is reported that global technical textile market in 2005 was over €70 billion, with average annual growth of around 4-5 per cent since 1995. It is predicted to reach €88 billion in 2010 (Ciabatti, 2007). The largest applications are transport, industrial and sport while the fastest growth will be in medical and hygiene products and geotextiles. In recent years, high-technology textiles have become a vital component of the output of the European textile industry. The consumption of technical textiles in Europe reached €35.6 billion in 2004 which is approximately around 40 per cent of global consumption (see Figure 4-10). The figure is expected to grow by approximately 17 per cent in 2010. Europe is not only the largest consumer and producer of technical textiles but also the most fragmented with 16 market segments. Its leading position in market and technology may provide the opportunity to set the global benchmark in a number of high-technology applications such as military and medical textiles.

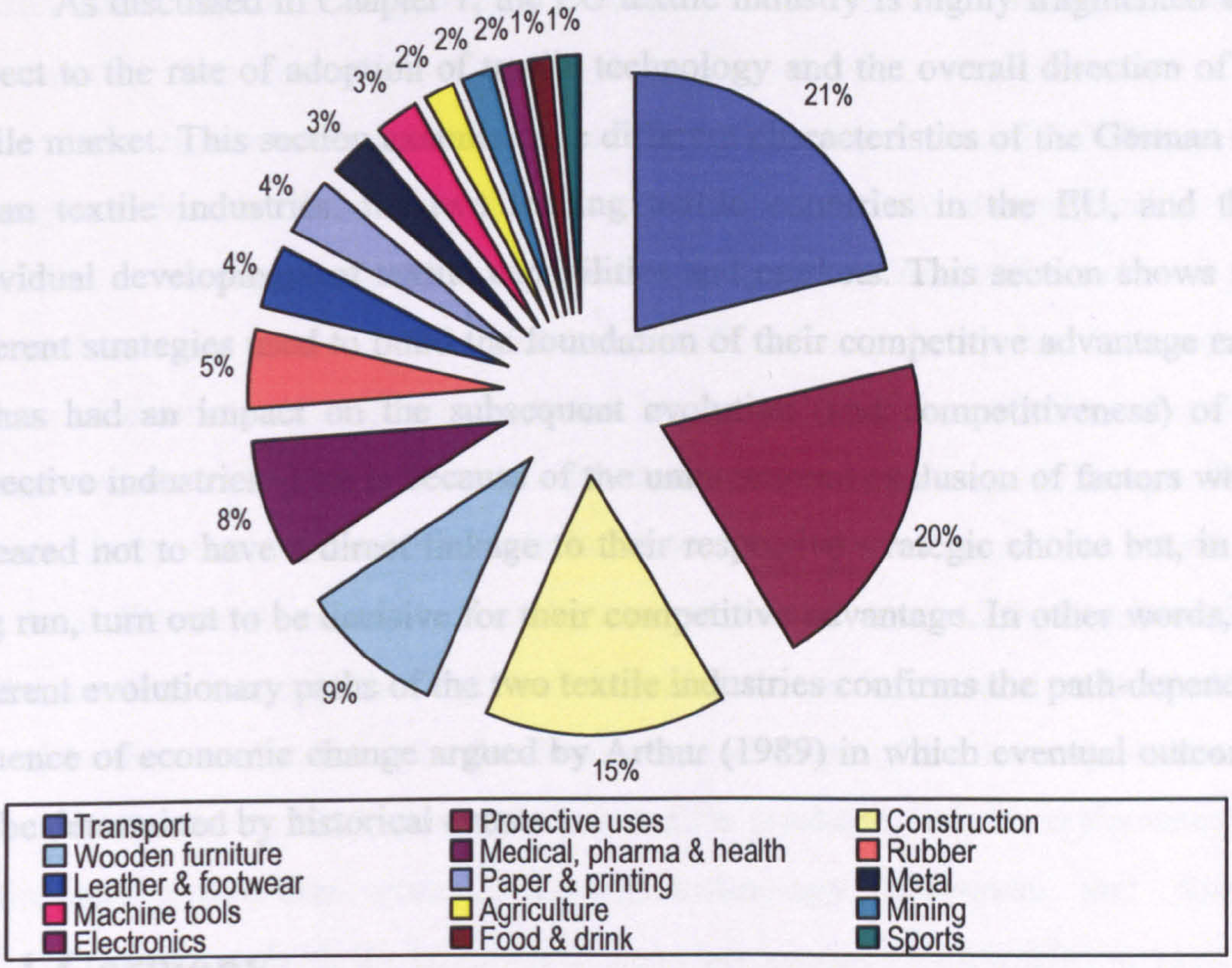


Figure 4-10. The consumption of technical textiles in Western Europe (2004)
Source: Euratex (2004) p. 13)

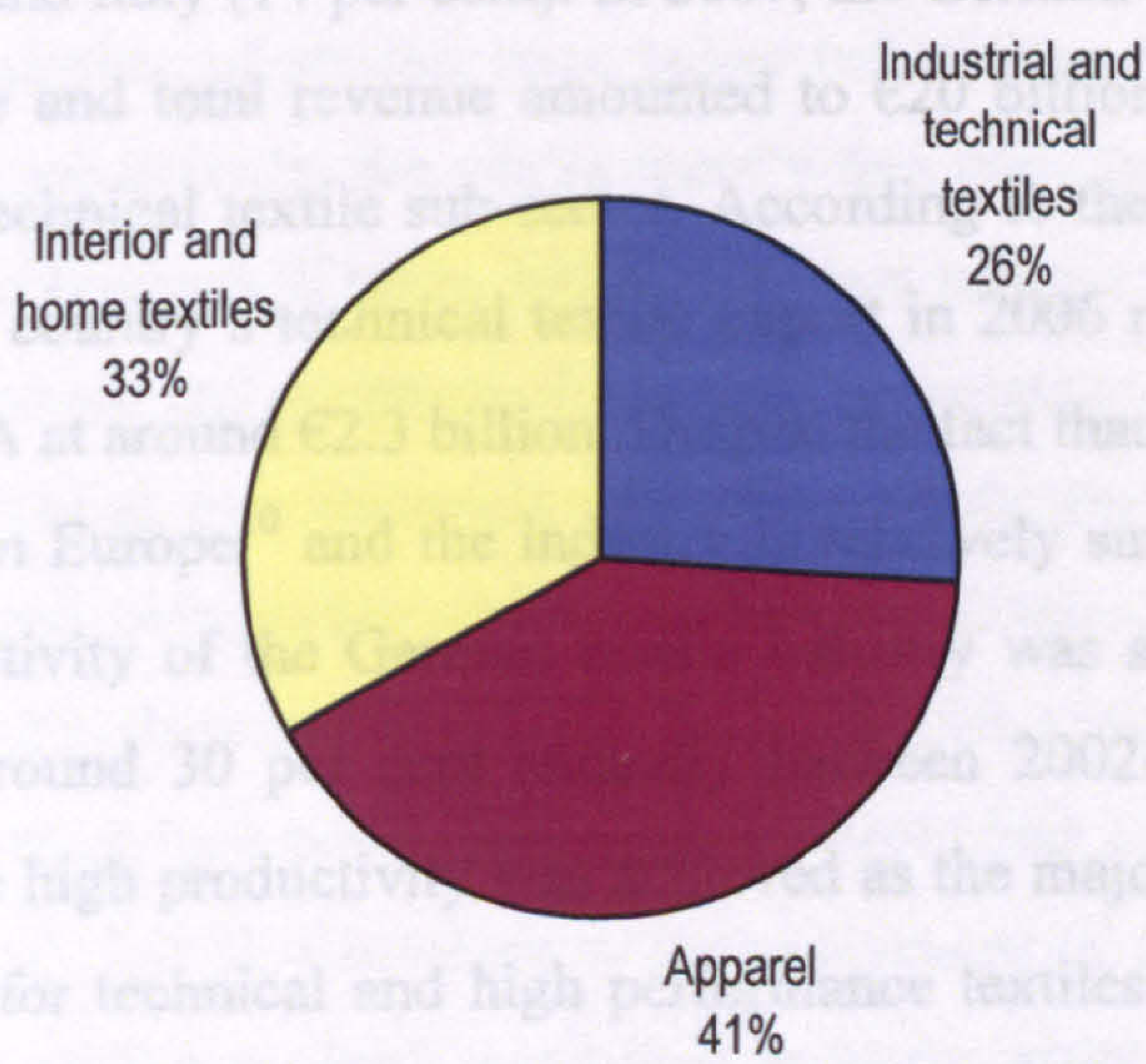


Figure 4-11. Breakdown of textile production into 3 sub-sectors by volume of fibre usage in 2003
Source: Euratex (2006) from CIRFS data

As discussed in Chapter 1, the EU textile industry is highly fragmented with respect to the rate of adoption of textile technology and the overall direction of the textile market. This section examines the different characteristics of the German and Italian textile industries, the two leading textile countries in the EU, and their individual development of textile capabilities and markets. This section shows that different strategies used to build the foundation of their competitive advantage early on has had an impact on the subsequent evolution (and competitiveness) of the respective industries. This is because of the unintentional exclusion of factors which appeared not to have a direct linkage to their respective strategic choice but, in the long run, turn out to be decisive for their competitive advantage. In other words, the different evolutionary paths of the two textile industries confirms the path-dependent sequence of economic change argued by Arthur (1989) in which eventual outcomes can be determined by historical events.

4.4.1 Germany

Between 2000-2005, Germany was the leading producer of technical textiles in Europe with 17 per cent market share, closely followed by France and the UK (16 per cent), and Italy (14 per cent). In 2007, the German textile industry employed 102 000 people and total revenue amounted to €20 billion, 40 per cent of which came from the technical textile sub-sector. According to the German Agency for Foreign Trade, the country's technical textile export in 2006 reached €2.7 billion, followed by the USA at around €2.3 billion. Despite the fact that Germany is a very high wage economy in Europe[10] and the industry is relatively small in size compared to Italy, the productivity of the German textile industry was significantly higher level than Italy by around 30 per cent annually between 2002-2004 (Eurostat, 2005, 2006, 2007). The high productivity was achieved as the majority of the production (40 per cent) was for technical and high performance textiles which generate considerably higher added value than other textile segments. The structure is fostered by the relatively high R&D intensity (two per cent) and high level of investment per employee in comparison to other textile industries in Europe. Arguably, the industry has experienced a transformation from being a low value-added, low-technology

[10] The German textile sector was within the top five highest average personal costs in Europe (Eurostat, 2006)

industry into a high technology industry that produces high added value goods for its customers.

The German textile industry is an interesting subject to study. Although the industry was devastated following two wars and painful industrial restructuring since the 1960s, it has successfully repositioned itself as the leader in the technical and high performance textile market since the 1970s. The industry has initiated the process of de-maturity itself through the creation of new competitive advantage underpinned by technological leadership rather than cost advantage. It is argued that the main factor that has enabled the industry to create a new competitive advantage was its ability to move away from low value-added cotton to high value-added textile products serving the high-end fashion and performance textile markets. Central to the transformation is the continuous adoption of the latest polymer and advanced material technologies into their textile products and the replacement of standardized production systems to high-technology equipment and flexible production systems. With the latter the industry can produce high quality products of different kinds with much greater flexibility than was previously possible. This strategy permitted the industry to adapt to changing demand and avoid commodity markets and the maturity-trap.

A number of studies have suggested various factors that contributed to its success. These include: the government's free trade policy which forced inefficient firms out of business (Dolan, 1983); the Nazi government's R&D policy to support the development and adoption of synthetic materials to reduce their dependency over imported natural raw materials (Hoschle, 2004); the closed relationship between industries and universities which has been established since the second half of the 19the century (Murmann, 2003); the industrial policy which promoted outward processing to reduce costs rather than mergers and acquisitions to reduce capacity (Toyne, *et al.*, 1984); the technical innovativeness of the supplier industries (Owen, 1999); and well-organised vocational systems which permitted sufficient skilled workers to be produced every year to rapidly adopt new technologies, to operate, maintain and repair machinery and to progress the transition towards flexible production systems (Nelson, 1987). Whilst those factors undoubtedly have contributed significantly to the sustained competitiveness of the industry, the question remains, however, on how the German textile industry has built up new capabilities and managed continuous change amid rapid environmental change. Continuous change needs to be highlighted in approaching the issue in question as it is believed to be the determining factor that has fostered the de-maturity of the German textile industry. In fact, the de-maturity concept as discussed in Chapter 2 emphasizes the ability of a firm to *continuously* change and innovate as the key success factor to adapt to the constantly changing business environment.

The ability to continuously change and innovate suggests that the culture and infrastructure of the organisation is built to encourage continuous innovation and that the process is embedded in its routines. These have to be built over a significant period to ensure that the necessary culture, infrastructure and systems are deeply entrenched in the organisation. As a consequence of this, continuous innovation is not dependent on a few people (tacit knowledge) but, rather, a part of the behaviour of the industry and innovation systems. This is the factor the Lancashire cotton industry lacked. As discussed in Chapter 3, the Lancashire textile industry certainly mastered a high degree of innovativeness in the 19^{th} century. However, the innovative capability appeared to erode following the First World War as organisational inertia hindered change.

On the contrary, innovation and continuous change have been the foundation on which the German textile industry was built. It remains its high priority today. *Openness to change* for improvement has been the noticeable character of the industry since the 19^{th} century. To illustrate this, the German textile industry was highly receptive to the adoption of synthetic dyes initially developed by IG Farben in Germany. As the synthetic dyes were not only cheaper replacements for imported natural dyes but, moreover, offered better performance –brightness, variety, durability- the rapid adoption of synthetic dyes improved the textile industry's competitive advantage. This had an impact on a remarkable increase in its competitiveness (Streb, *et al.*, 2007).

In a similar fashion, the industry's receptivity to synthetic dyes created close cooperation between the chemical and textile industries through which further improvement of dyes was achieved. This contributed significantly to the ability of the German synthetic dye industry to overtake Britain's leadership in the field, despite the fact that a British scientist, William Perkins, discovered the substance in

1856 (Murmann, 2003)[11]. By the first decade of the 20th century, within 30 years after its first attempt to develop its own version of synthetic dyes, five German chemical firms (BASF, Bayer, Hoechst, Casella and AGFA) controlled 75 per cent of the global synthetic dye market.

Openness to change of the industry encouraged IG Farben to develop nylon 6 in its attempt to reproduce nylon 6.6 without breaching the patent of the latter which belonged to DuPont. The German firm creatively used ring-opening polymerization (as opposed to condensation polymerization used to produce nylon 6.6) to produce synthetic fibres with similar properties. Nylon 6 has an advantage over its competitor as the process is easier and cheaper. The German textile industry rapidly responded to this new development through the development of new products for military use such as tire cords, parachutes and tents prior to World War II and replaced the use of natural fibres in these applications.

In the engineering field, Germany has taken over Britain's leadership as the world's largest textile machinery producer since the 1970s. In 1970 Germany dominated the textile machinery export market with 30 per cent market share whereas Britain only had 12 per cent down from 80 per cent during its heyday (Singleton, 1997). Hereafter, the German textile machinery industry has maintained its leadership in the field with around 25 per cent market share. According to Singleton, the tremendous achievement made by the German textile machinery industry rested on its creativity to search for new opportunities. The textile and textile machinery industries found it difficult to compete with the British textile and machinery markers which dominated the standardized textile machinery market for the production of mass volume products in the 19th century. Therefore, the German textile machinery industry opted to specialise in machinery with greater flexibility for niche markets and higher-quality textile products. Such a strategy gave a competitive advantage to the textile and machine-tools industries as the textile market changed from mass production to specialisation in the 1970s which required highly flexible equipment.

[11] Murmann also argues that the absence of patent system in the country allowed a large number of firms to enter the market in the 1860s and 1870s by simply imitating the original invention. The situation led to greater competition through which a selection process took place. Those who survived in such fierce competitive environment were equipped with the capability to advance the technology and quality, as well as to reduce cost. Britain, on the other hand, underwent slow development due to entry barriers erected by the patent system. As a result, the competitive German firms successfully competed in the domestic and international markets.

This suggests that Germany's advances in chemicals and engineering, the close relationship between the chemical, engineering industries and the textile industry and the latter's openness to adopt new technologies provided the foundation for its long-term growth. Singleton (1997), however, is less convinced that the advancement of the domestic textile machinery and chemical fibre industries is essential for the success of the textile industry on the grounds that the international market for these inputs is highly developed. Under these circumstances, he argues, textile firms can purchase the inputs from different sources. His argument, however, appears to refer to the production of commoditised textile products where textile firms in Europe can source commodity fibres, such as nylon and polyester, and standardized equipment from China to make shirts. It is argued here, however, that in the case of the German textile industry, the advancement of the supplier industries and their close proximity were critical factors for continuous change. These factors facilitated interactions and learning and thus rapid and continuous dissemination of information from the suppliers to the textile firms and vice versa. Textile firms have the advantage to obtain information about the latest development(s) earlier than their competitors and to find the partners to develop prototypes. Under these circumstances, there is an opportunity to capitalise from the advantage of being a first mover. Moreover, as the decision to adopt emerging technologies required a thorough technical and economic know-how, close proximity to the suppliers helped textile firms to make informed decisions.

Indeed, the case study of Freudenberg clearly suggests that close cooperation between textile firms, textile machinery manufacturers and chemical producers is vital to the process of diversification, new product development and the creation of new competencies. In fact, in many cases, successful product development is motivated by new inventions made by the supplier industries. The case study thus suggests that, contrary to Singleton's argument, the advancement of the supplier industries, close proximity and cooperation indeed has helped the firm to develop a culture of continuous change.

The role of government also appears to be critical not only in the adoption of technology but also in the course of the development of the industry. The country's reliance on imports of raw materials for textiles was considered to be strategically disadvantageous during war time as trade blockades interrupted national supplies.

The Nazi government reinforced the self sufficiency policy to reduce dependency on imports (British Intelligence Objectives Sub-Committee, 1946) through subsidies for textile manufacturers to invest in synthetic fibre manufacturers and to progressively adopt synthetic materials into their products. By 1939, most German textiles had some synthetic contents (Hoschle, 2004). The policy facilitated learning and appreciation over the advantages/disadvantages of synthetic materials. This helped rapid diffusion of the technology not only into several firms but into the entire textile industry. The new knowledge enabled textile firms to develop higher value-added textile products for technical textile markets initially facilitated by demand from the military, most notably the army. The new capability provided the industry with an alternative avenue for growth when their traditional market started to collapse in the 1960s. This highlights the different approaches of the German and British governments. It appears that the former encouraged change whereas the latter tended to maintain the status quo.

The development of non-woven technology illustrates how government policy, advances of supplier firms and close proximity with suppliers and markets have helped Freudenberg to adapt to changes in technology and demand. Those factors facilitated the development of new competencies by which it shifted away from its established development path. In Chapter 7 it is explained that government policy in the adoption of synthetic materials led to one of the greatest inventions in the textile innovation history, that is, nonwoven fabrics. In the early 1930s, Freudenberg, a German leather tannery, was forced by the government as well as by a changed business environment to search for the replacement of leather as imports of the raw materials disappeared. Together with IG Farben and the machinery makers the firm developed materials to substitute leather made of cotton fibres which were bonded together with synthetic rubber to form nonwoven layers. With the discovery of synthetic materials Freudenberg enhanced the quality of its nonwoven fabrics and extended the applications.

The firm continuously adopted new materials -thermoplastics (such as polypropylene and polyester), elastomers, silicone, PTFE and fluorubber- and processing technologies that would help it to diversify and reinforce its competitive position. The firm's filter business, for instance, has developed from focusing on the automotive industry to focusing on a range of industries including aerospace, clean room, office filtration, and medical applications. Freudenberg's nonwoven technology has been employed to produce a vast range of products ranging from diapers, wipers, filtration, tea bags, surgical drape, medical dressing and apparel, to geotextiles, roofing and floorcoverings, automobile carpet backing and wound dressings. Such a diversification strategy has become the competitive advantage of the firm as its diversified markets, to a great extent, have secured it from the volatility of demand which often occurs in these user industries.

In addition to replacing the existing products, nonwoven also fostered the emergence of the revolutionary disposable market such as diapers, wipers, tea bags and a variety of hygienic and medical textiles. The production of nonwovens is characterised by high productivity and very low production costs as it does not involve a weaving or knitting process. The cost factor which is negligible permits the creation of disposable markets. Disposable products have become an important part of an individual's daily activities. As the nonwoven market is one of the fastest growing markets in the textile sector, Freudenberg expects to continue to grow in the future. Freudenberg is the oldest and largest nonwoven producer and remains so up to the present day.

Despite its leadership in the technical and high performance textile market, the German textile industry is not necessarily immune to changing economic conditions. Demand for these textile products is largely dependant on the growth of the user industries (Singleton, 1997). For instance, the collapse of the US automotive industry in 2008 hit technical textile manufacturers who supplied textile products to the industry. Freudenberg, for instance, had to close one of its plants in North Carolina which supplied nonwoven fabrics to the US car makers. In contrast, growing demand in ballistic proof fabrics following the global war on terror launched in 2001 brought about rapid growth for firms who supply this market. Ten Cate, one of the leaders in ballistic protection fabrics experienced 17 per cent growth in 2008, the highest among the 20 largest textile firms in Europe. In addition, the sector is also not immune to product and market maturity and growing global competition (Horrocks and Anand, 2000). Therefore, the leadership of the German textile industry in this sector depends on its ability to perpetuate its innovative culture and systems from one generation to the next. This will foster continuous development of new products and the creation of new markets.

According to Textilwirtschaft Magazine which publishes information about the top 20 European textile firms (in terms of turnover) each year, the German textile industry was represented by six firms in 2007-2008. Germany and Italy are the only two countries that have been represented by more than four firms on the list since 2005. A striking contrast of the characteristics between the German and Italian firms is on their product and market focus. The German firms are the manufacturers of highly diversified technical and high-performance textiles, the majority of which contain synthetic materials. The Italian firms, on the other hand, supply high quality wool, cashmere and silk fabrics for the luxury fashion market. Over the years, German firms developed different products for a wide range of markets with the adoption of synthetic materials and the relevant processing technologies. This has helped them to vastly diversify their products to serve various niche markets in different industries. For the Italian firms, on the contrary, product diversification has been based on the quality of yarns (counts) and aesthetic designs, all of which are manufactured to serve the high-end fashion industry. The relatively more concentrated market (in comparison to the German textile industry) makes the Italian firms more vulnerable to changes in demand. This is discussed in greater detail in the following section.

4.4.2 Italy

Italy is the largest textile and clothing producer in Europe. In 2006, the sector constituted 25.5 per cent of the total turnover of the EU textile and clothing sector, and represented 37 percent of the total number the EU textile and clothing firms. The sector remains crucial to the country's economy, representing 10 per cent of the total turnover of the manufacturing sector, seven per cent of total manufacturing production and 11 per cent of manufacturing employment in 2006 (Sistema Moda Italia, 2006). Unlike Britain which used to be prominent for its standardized textile products or Germany for its technical textiles, Italy is well-known for its high-end fashion brands which emerged in the mid 20th century. While other European countries such as Germany, the UK and the Netherlands have shifted their textile and clothing capabilities to technical and high performance textiles, Italy remains focused on traditional textiles for the clothing market (82 per cent in 2006) and trails behind in technical and high performance textiles.

The Italian textile industry has been under immense pressure over the past decade. It has been in long-term decline where the rate of exports has declined whereas imports have increased considerably. In the past eight years, the loss of employment has reached more than 100 000 jobs - or around 20 per cent of the industry's current level of employment. In 2008 the loss of employment reached 6000. This shows that even the high-end textile fashion market is not immune from the effects of cost-based competition because of the emergence of new low-cost competitors and changing demand for quality products at more affordable prices.

Cost pressures have forced the industry to increase its outward-processing activities mainly to Eastern European countries. More controversially, it was revealed that a number of Italian luxury fashion brands manufacture their products in China (Economist, 2009). This practice has occurred for several years but been protected under a secrecy agreement. Disclosing such a practice would very likely to damage the reputation of 'Made in Italy' which has been the industry's distinct characteristics and competitive factor. In terms of changing demand, in contrast to the 1980s where consumers willing to pay premium prices for fashion products, the consumers in the late 1990s onwards have become much more value driven and demanding more for less prices. High-end fashion brands including Stella McCartney and Armani responded to such a trend through the production of secondary lines at much more affordable prices to reach-out to larger markets. Recently, Jimmy Choo, a high-end fashion brand, designed shoes for H&M, a low-price high-street fashion brand.

It appears, however, little effort has been made to respond to these trends. The majority of the industry's stakeholders remain adamant that the decline is temporary and ignore the possibility that the change could be permanent. They believe that as long as the speed of delivery and production flexibility can be improved the Italian textile industry will regain its competitive edge (Bruni, 2004). Therefore, the adoption of more modern technologies to improve speed and flexibility is more prevalent among the Italian firms than a more radical approach such as the creation of new markets.

This attitude mirrors that of the Lancashire cotton industry in the early decades of the 20th century during which the threat posed by the emergence of Japanese firms as low-cost cotton textile producers was largely ignored. As discussed in Chapter 3 Japan's success was built on very different foundations. The Lancashire firms made attempts to defend their competitiveness through measures they were very familiar with but it was all in vain. As discussed in Chapter 1 and 3, history has repeatedly shown that failure to change and adapt to environmental changes could have a devastating impact on industry. It appears that the Italian textile industry is falling into the maturity-trap just as the British industry did.

In contrast to the strategy of the German textile industry, attempts to increase its share in the technical textile sector have been largely overlooked by the Italian textile industry. As shown in Figure 4-12, Italy's technical textile consumption has only been around 12 per cent Europe's total consumption since 2000 (Ciabatti, 2007). As for production, Italy has constituted 16 per cent of Europe's total production since 2005, leaving it behind Germany, France, UK, and Belgium. In terms of employment, the technical textile sector employed 6000 workers in 2004 which only represented one per cent of employment in the country's textile and clothing industry. A study on innovation activities in the Italian textile industry in the 1980s and 1990s suggested that R&D activities by textile and clothing firms to promote innovation did not play a key role. The purchase of new textile machinery remained the most important aspect of the innovation front, followed by design and customer demands (Rolfo and Calabrese, 2003). The competitiveness of firms seems to be more determined by design and marketing than innovation where it has not been proactive for a very long time.

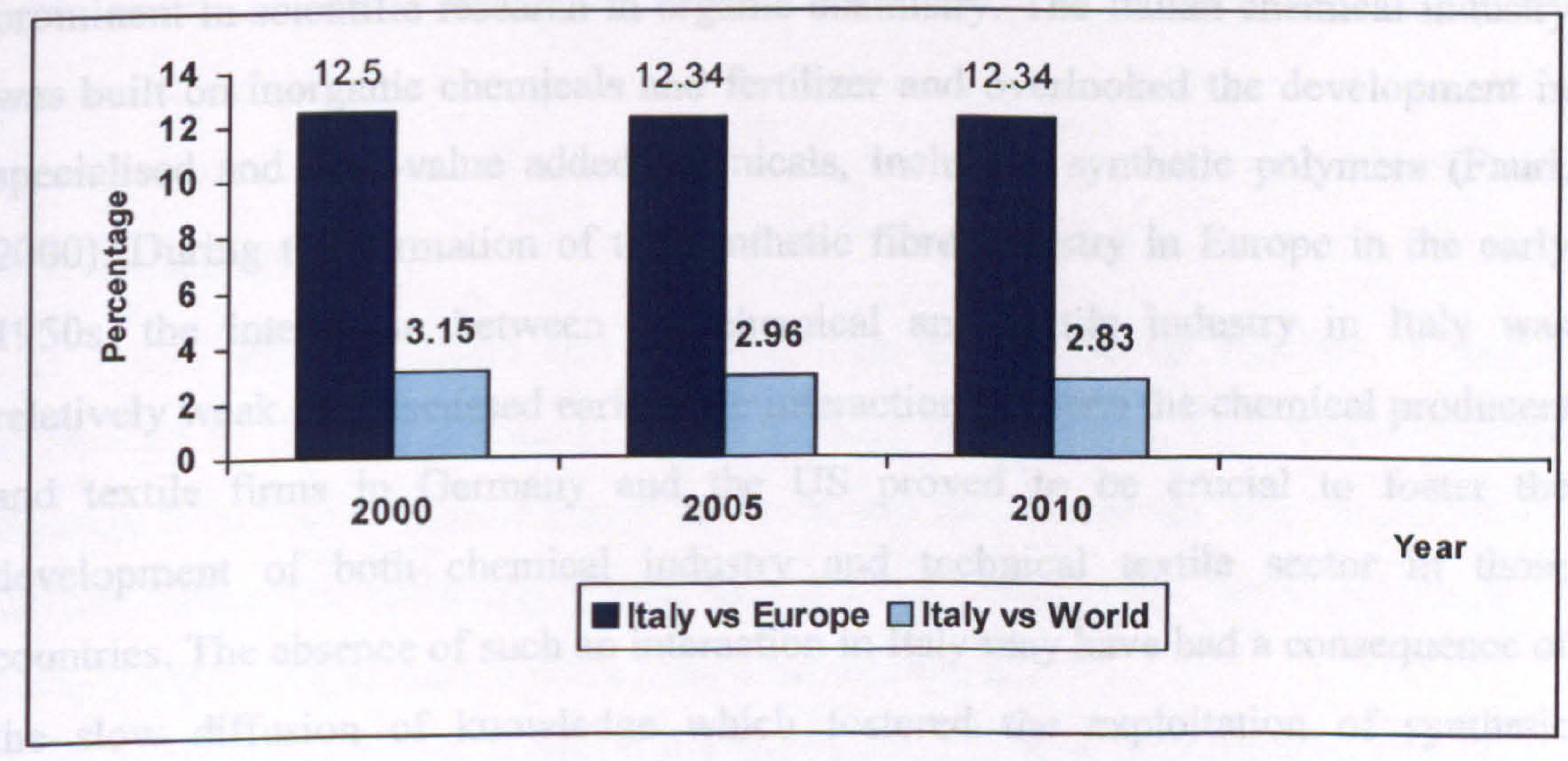


Figure 4-12. Technical textile consumption, Italy vs Europe and Italy vs the world
Source: Ciabatti, 2007

The experience of the German textile industry suggests that the development of high-technology textiles requires not only the adoption of more modern equipment. Equally important is the adoption of knowledge in synthetic fibres and advanced materials. The Italian textile industry has been proactive in the modernisation of their machinery supported by their progressive textile machinery industry which has been the second largest exporter after Germany since the mid 1990s. In fact, their level of investment in textile and clothing machinery between 1996-2002 was the highest among the EU countries, with its share in the apparel sector being particularly remarkable, representing around 50 per cent of the total investment in the EU (Guercini, 2004). This has improved the flexibility of their production systems which is critical to enable them to adapt to the increasingly rapid changes in the fashion market –the industry's main market. In the adoption of synthetic and advanced materials, however, the industry has been trailing behind its competitors in the other West European countries, leading to a less-developed technical textile sector. As a consequence of this, despite its larger size, productivity of the Italian textile industry has been much lower than the Dutch and the German textile industries (around 30 per cent) since 2002 (Eurostat Publication, 2005, 2006 and 2007).

The slow adoption of synthetic polymers and advanced materials by the Italian textile industry appears to be significantly influenced by the historical context of the development of the industry. In contrast to Germany, Italy has not been prominent in scientific research in organic chemistry. The Italian chemical industry was built on inorganic chemicals and fertilizer and overlooked the development in specialised and high-value added chemicals, including synthetic polymers (Fauri, 2000). During the formation of the synthetic fibre industry in Europe in the early 1950s, the interaction between the chemical and textile industry in Italy was relatively weak. As discussed earlier, the interaction between the chemical producers and textile firms in Germany and the US proved to be crucial to foster the development of both chemical industry and technical textile sector in those countries. The absence of such an interaction in Italy may have had a consequence of the slow diffusion of knowledge which fostered the exploitation of synthetic materials into textile products. In contrast, the relationship between fashion houses/designers and textile manufacturers has been well established since the early 1950s. This may have strongly influenced the development trajectory of the industry.

The experience of the Italian textile industry shows that the slow adoption of polymer and advanced material technologies has led the industry to focus on a narrow range of markets, mainly exploiting the properties of natural fibres. As argued earlier, such a concentrated market poses a threat to the industry if global demand changes. Broader market segments and a greater variety of technologies can help the industry to manage the risk that will arise because of changes in technology and demand and be more flexible to respond to such changes. This factor may have contributed to the problem the industry is now facing as its established market has started to change.

Only in recent years has the industry begun to appreciate the importance of technical textiles for the future of its textile and clothing sector. From the trade balance data in 2004, technical textiles constituted 19 percent in the textile sector or 9.4 percent for the total textile and clothing sector (Sistema Moda Italia, 2004). The country's increased commitment to R&D has been shown through the commitment of around €3 to €5 billion annual funding starting from 2003 to find new solutions in technical textiles. Attempts to improve the industry's technical knowledge and skills in technical textiles are expected to enhance their capability in the development of new products and processes in more competitive markets. Nonetheless, the Italian current technical textile products remain limited to some traditional markets, mainly home textiles, clothing, and sports, all of which have become much less competitive because of competition from producers in developing countries.

4.5 Conclusion

This chapter shows that the evolution of the textile industry is highly influenced by continuous changes in technology and demand. This reveals that the industry is far more dynamic than it has been widely believed. In fact, the industry is shifting towards a knowledge-based industry and riding itself from the image of being traditional and mature it has long been referred to.

This suggests that textile firms are exposed to new opportunities offered by emerging technologies and markets. Materials science and engineering has proved to play a central role in the advancement of the textile industry. The technology fosters product customisation for niche markets. Consequently, the market for the textile industry has become increasingly fragmented. To capitalise on the development of this scientific and technological domain, textile firms have to have the capability to adopt and use relevant knowledge and know-how to develop competitive products. This, however, requires not only new technical capabilities but also changes in R&D and technology strategy, business and marketing practices and organisational structure and routines. These organisational capabilities help textile firms to optimise the exploitation of their new technical capabilities so as to be more competitive in the new competitive environment.

The German chemical industry with its long history of innovation in synthetic polymers has been successful at the transfer of knowledge and know-how to the textile industry much earlier than their competitors in Europe. A solid relationship between the chemical, engineering and textile industries which has been established since the 19^{th} century has helped the textile industry to continuously change to adapt to changing external conditions. The German textile industry has managed to become more akin to a high-technology industry and has maintained its leadership in the development of technical and high-tech textiles since the 1960s.

Italy, the largest textile nation in Europe, on the other hand, has been caught out by the effects of competition from low-cost competitors which has overwhelmed the industry. Its customers have also changed their preferences to high quality at affordable price and are no longer willing to pay premium prices for fashion products. This suggests that their strategy to base their competitiveness on quality and design which has been very successful since 1970s appears to have run its course. The industry's stakeholders, however, remain adamant that the change is temporary. A more radical approach to build up new capabilities in high-technology textiles is deemed to be less important than incremental improvements to improve the industry's responsiveness to the fluctuations in demand -through the adoption of flexible production systems. From the experience of the British textile industry it appears that that the Italian textile industry is falling into the maturity-trap.

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5

Marzotto: Falling into the Maturity-Trap?

5.1 Introduction

As discussed in Chapter 4, Italy is the largest textile and clothing producer in Europe and prominent for its quality, design and luxurious appearance. The industry has grown significantly since the Second World War. The war provided new opportunities to local manufacturers as imports from major competitors, that is, France and Britain, were disrupted (White, 2000). This initiated the rapid growth of the Italian fashion industry.

In contrast to its counterpart in Britain, the Italian textile industry has focused on its domestic and European markets rather than exports to low-cost countries at least until the early 1980s. As its markets demanded higher quality, more fashionable and frequent changes the industry built up a capacity to produce high quality fashionable products with flexible production. The adoption of new equipment has been the main source of technical innovation and the natural fibres have been the main raw materials.

As mentioned in Chapter 1, flexibility has been the distinctive feature of the Italian textile industry (Djelic and Ainamo, 1999). The structure which is made up of a large number of small enterprises operating in networks has enabled the Italian fashion houses to reconcile flexibility with almost limitless production capacity. The setting also allows for the production of a wide variety of products within a relatively short time period. As a result, the firms have been able to avoid price sensitive product lines and focus on niche markets rather than economies of scale for efficiency (Guercini, 2004).

As discussed in Chapter 4, the prominent reputation of 'Made in Italy' was built up after World War II following the introduction of the prêt a porter collection. It was developed from the combination of America's mass production technique with Italy's prominent craftsmanship (White, 2000). Hereafter, the Italian textile industry has experienced a radical transition from a craft-based production into a large-scale, automated production system. Continuous adoption of the American machinery has improved the productivity by 400 per cent within less than two decades and the industry achieved the highest productivity in Europe by 1987 (Antonelli and Marchionatti, 1998).

The Italian textile and clothing sector enjoyed substantial growth from 1976 when other European leading textile producing countries, that is, France, United Kingdom, and (West) Germany, were stagnant or in decline. Unlike in Britain and France, it appears that the Multi Fibre Agreement positively affected the Italian textile and clothing industry. During the period of protection, a large number of Italian fashion houses emerged, signifying the rise of the Italian luxury fashion industry.

Following its success in the 1970s and 1980s, the industry encountered difficulties because of the recession in the 1980s, intensified competition in the single European market (EU) and gradual liberation of industrial protectionism in the developed countries. Moreover, a new wave of low-cost competitors and the growth of large retailers which tended to place large orders for more standard styles and quality have unsettled the foundation of the industry as it was built up to compete in an entirely different environment. Consequently, the industry started to experience a long-term contraction. Production declined by around 30 per cent between 1997-2006, about 100 000 firms disappeared between 1990-2006 while the loss of employment reached over 3 per cent per year between 2001-2006 (Camera de Nazionale della Moda Italiana, Jan-2006). Although exports have showed a steady increase since 2003, the pace of imports increased at a faster rate. Hence, the trade balance has gone into a sharp decline (Figure 5-1).

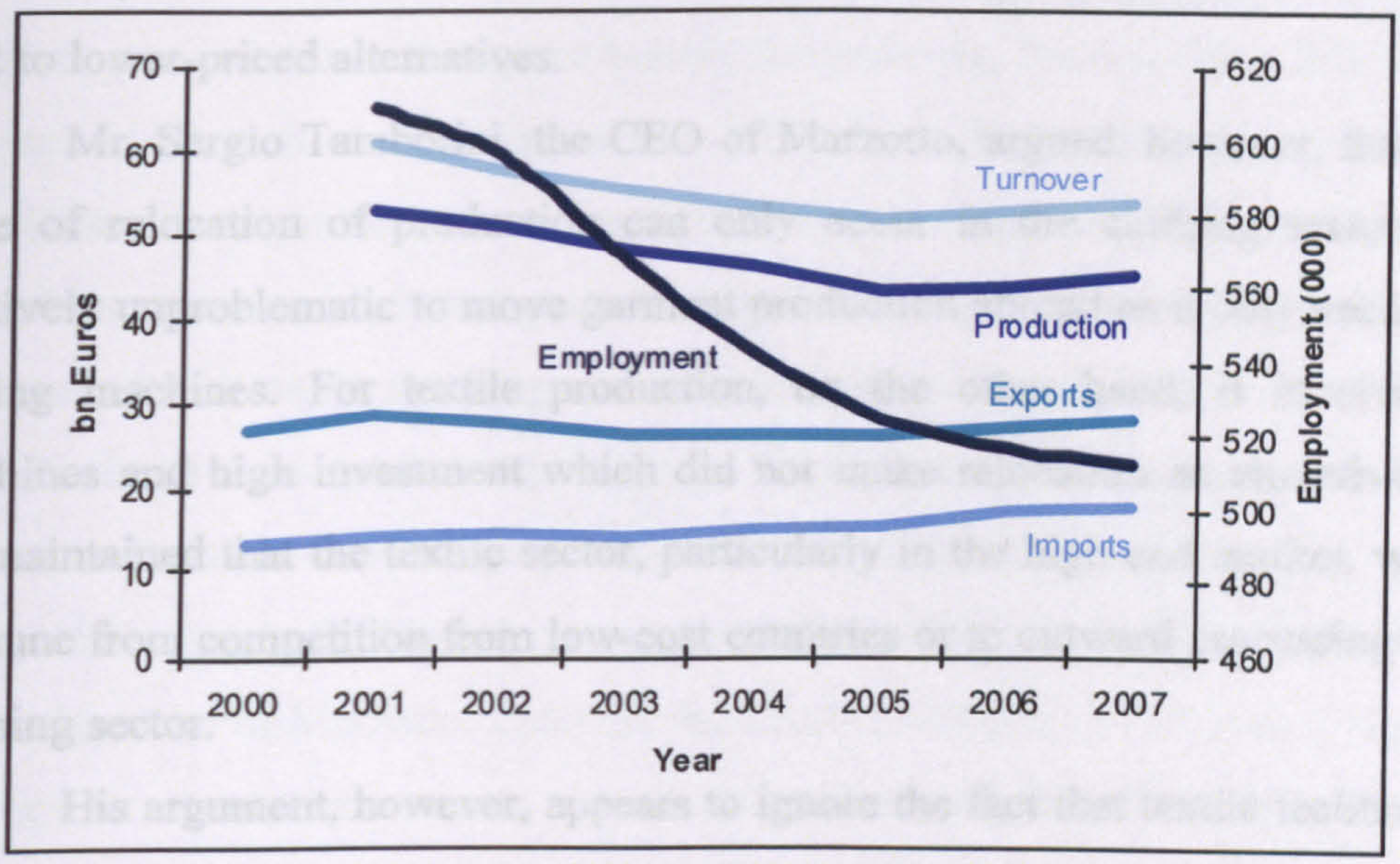

Figure 5-1. The performance of Italian textile and clothing sector, 2001-2006

Source: Sistema Moda Italia, 2007

Since the late 1990s, the Italian textile industry appears to have moved towards maturity. The industry has become highly concentrated as a large number of acquisitions have taken place since the late 1990s. Currently there are only five large groups of high fashion firms which own the majority of luxury fashion labels. Cost pressures have forced the firms to relocate its production to lower cost countries, more than two decades after Germany initiated the approach. Benetton, for instance, set up factories in Croatia, Hungary, Spain and Portugal; and Marzoto established plants in Lithuania, Tunisia and Czech Republic. More alarmingly, according to Galloni et al. (2005), the vast majority of luxury labels such as Valentino, Gucci and Armani have made parts of their collections in North Africa or Eastern Europe. They reveal that a number of Italian textile and clothing executives believe that the main lines of luxury brands will be entirely relocated within the next 15 years. The quality of 'Made in Italy' which has long been the industry's mark of quality for decades is in jeopardy; hence the call for new innovative solutions to save the industry from a bleak future.

This change shows that the dynamism of market demand and economic development in different countries may potentially affect the domination of Italy in the fashion market. The luxury product market which has been assumed not to be affected by cost-competition has shown a sign of change. Customers have started to shift to lower-priced alternatives.

Mr. Sergio Tamborini, the CEO of Marzotto, argued, however, that a large scale of relocation of production can only occur in the clothing sector. It was relatively unproblematic to move garment production abroad as it only needed small sewing machines. For textile production, on the other hand, it involved large machines and high investment which did not make relocation an attractive option. He maintained that the textile sector, particularly in the high-end market, was more immune from competition from low-cost countries or to outward processing than the clothing sector.

His argument, however, appears to ignore the fact that textile technology for the traditional textile market has reached maturity so that any firm with sufficient financial resources can buy the latest equipment. Relocating textile production may be problematic, but buying the most modern equipment for China (or India) is not a problem given the growth rate of China's GDP (10 percent in 2007, 9.8 percent in 2008). Furthermore, the size of the Chinese population (1.2 billion people) and the rapid growth of the country's middle-class provide it with sufficient cheap labour and a vast domestic market. Moreover, a significant number of Chinese students have received a Western education and work experience in Europe and the US over the past decade. This undoubtedly will foster the growth of skilled talent. If a Chinese firm can buy IBM and an Indian firm can buy Jaguar, it is possible that troubled a Western luxury fashion firm can be taken over by firms from the developing countries when they are facing financial difficulties.

The experience of the Italian textile industry shows that an industry with a dominant power in a market segment that is widely believed to be immune from cost-competition has stumbled in the face of the emergence of new low-cost competitors and a shift in demand. It appears that the decline of the Italian textile industry paralleled with that of the French made-to-measure collection when it was challenged by lower-priced alternatives offered by the Italian textile industry. Thus, history may repeat itself if the Italian textile industry can not find viable solutions to its problems.

The case study of Marzotto examines the capability of a traditional textile firm operating in the high-end market segment to adapt to a changing competitive environment. The study found that the firm recognised that market changes were happening at faster rate than ever before. Surprisingly, however, the firm's strategy to respond to such changes appears to be highly influenced by its past strategies which have brought success to the firm. Using the maturity-trap and the dynamic capabilities framework, it is argued that the firm's strategy is insufficient to maintain its competitiveness in the long-run. Marzotto shows organisational inertia that is very likely to lead to the maturity-trap. Under such circumstances the firm may become vulnerable to a changing competitive environment.

This chapter is divided into seven sections. The next section briefly discusses the background of Marzotto. Later on, the firm's perception about innovation and the strategy to achieve its business objective are discussed. In section four, the detailed process of resource configuration by which the firm has diversified its business is examined. The implication of this to the evolution of the firm's competencies and the dynamic capabilities are elaborated on.

5.2 Marzotto

Marzotto has long been known as one of the largest textile and clothing companies in the world, and the largest textile manufacturer in Italy. The firm was established in 1836 by Luigi Marzotto in Valdagno (Veneto) as a manufacturer of woollen fabrics. It belongs to the founder family who purchased the share from the Milan Stock Exchange back into the family's ownership. Marzotto employed 3300 people and made €6.5 million in profit (2007).

The firm has diversified to include the manufacture of cotton fabrics and wool and linen yarns. It competes in four different segments (in accordance to quality and price) which are sold in four different brands (Figure 5-2). In terms of raw materials, the firm maintains its established traditional products in wool and cotton. Between 1973-2005, the firm diversified into clothing and luxury fashion brands that included Hugo Boss and Valentino. However, the clothing business was demerged in 2005. The firm stated it would concentrate on its high-end textile markets as it believes that the textile business can provided longer-term competitive advantage than the clothing sector.

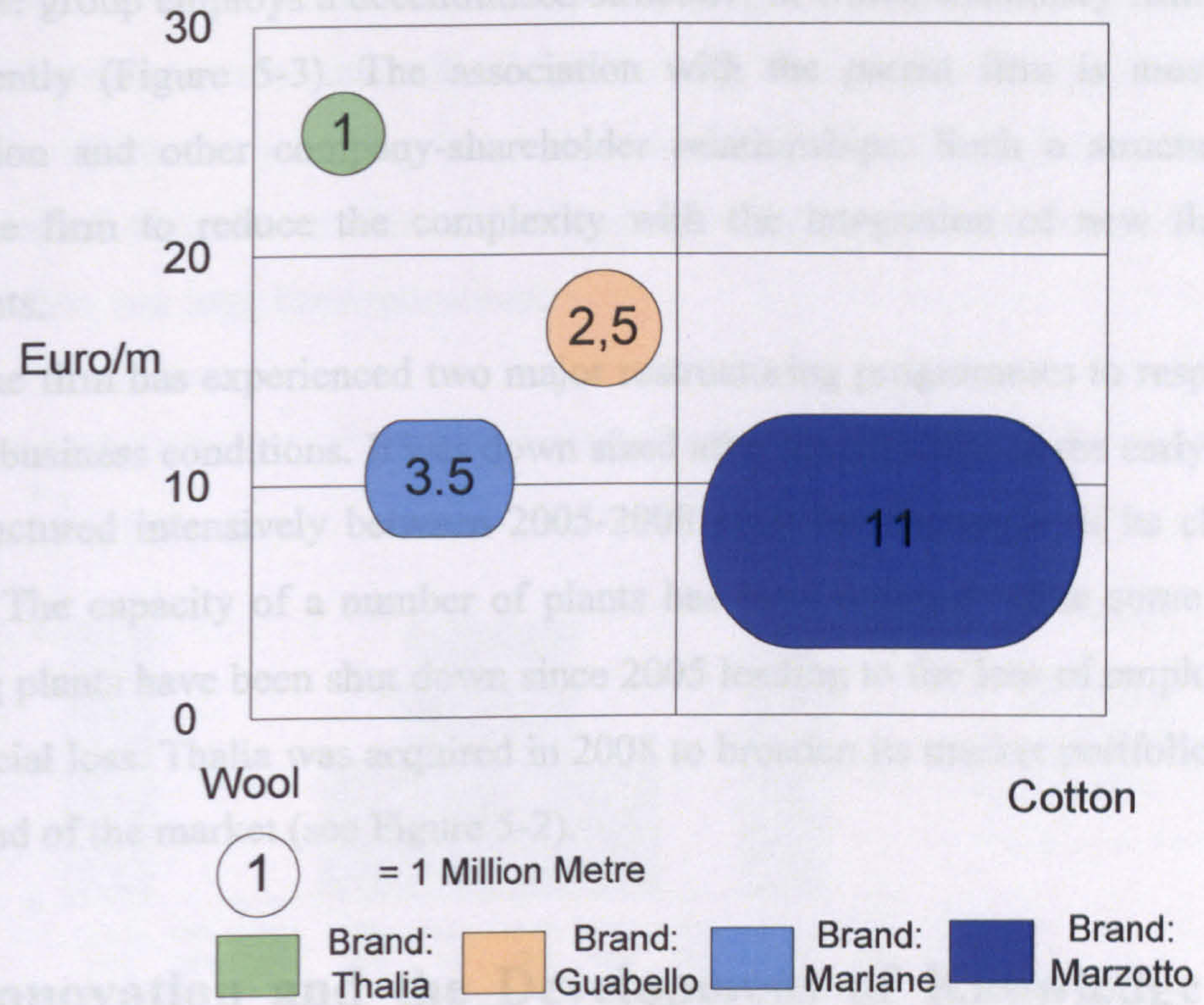

Figure 5-2. Product portfolio of Marzotto (2008)
Source: Interview with the CEO of Marzotto

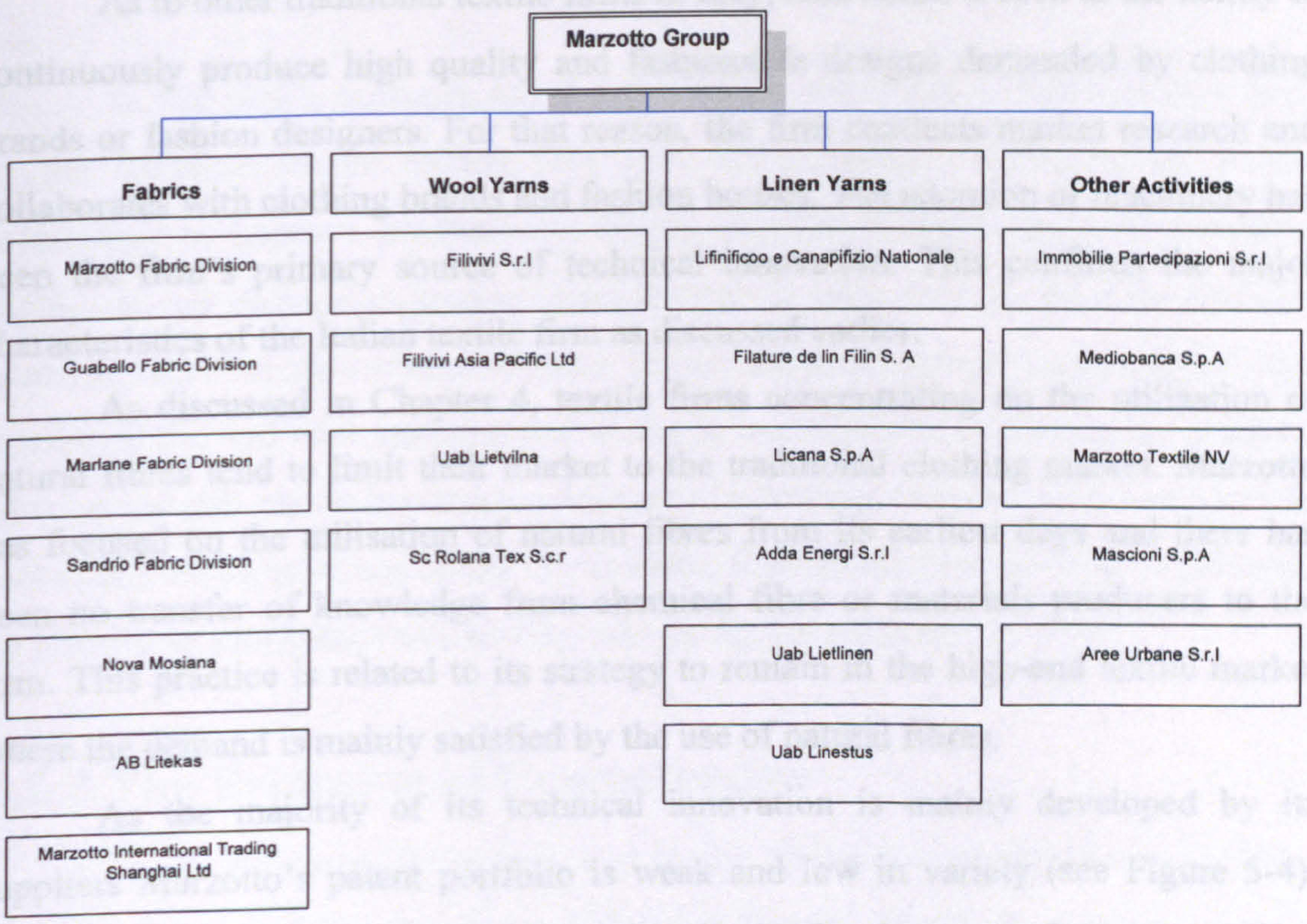

Figure 5-3. Organisational structure after demerger (2006-2007)
Source: Annual Report

The group employs a decentralised structure, in which subsidiary firms work independently (Figure 5-3). The association with the parent firm is mostly for coordination and other company-shareholder relationships. Such a structure has helped the firm to reduce the complexity with the integration of new firms or divestments.

The firm has experienced two major restructuring programmes to respond to changing business conditions. It was down sized after the oil crisis in the early 1970s and restructured intensively between 2005-2008 after the demerger of its clothing business. The capacity of a number of plants has been reduced while some of the remaining plants have been shut down since 2005 leading to the loss of employment and financial loss. Thalia was acquired in 2008 to broaden its market portfolio in the highest-end of the market (see Figure 5-2).

5.2.1 Innovation and the Development of Knowledge and Competencies

As to other traditional textile firms in Italy, innovation is seen as the ability to continuously produce high quality and fashionable designs demanded by clothing brands or fashion designers. For that reason, the firm conducts market research and collaborates with clothing brands and fashion houses. The adoption of machinery has been the firm's primary source of technical innovation. This confirms the major characteristics of the Italian textile firm as discussed earlier.

As discussed in Chapter 4, textile firms concentrating on the utilization of natural fibres tend to limit their market to the traditional clothing market. Marzotto has focused on the utilisation of natural fibres from its earliest days and there has been no transfer of knowledge from chemical fibre or materials producers to the firm. This practice is related to its strategy to remain in the high-end textile market where the demand is mainly satisfied by the use of natural fibres.

As the majority of its technical innovation is mainly developed by its suppliers Marzotto's patent portfolio is weak and low in variety (see Figure 5-4). Indeed, its only patent in product technology is the development of electric woollen blankets with embedded electrically-conductive elements. The rest of the patents are related to treatments of wool fibres and product designs. The firm's internal development has been focused on the new combinations of fibre blends such as the mixture of cashmere, wool and silk. Together with the equipment suppliers the firm focuses its efforts on adopting innovative weaving and spinning processes. The activities are designed to maintain the image of luxury, elegance and opulence for which the firm has long been renowned.

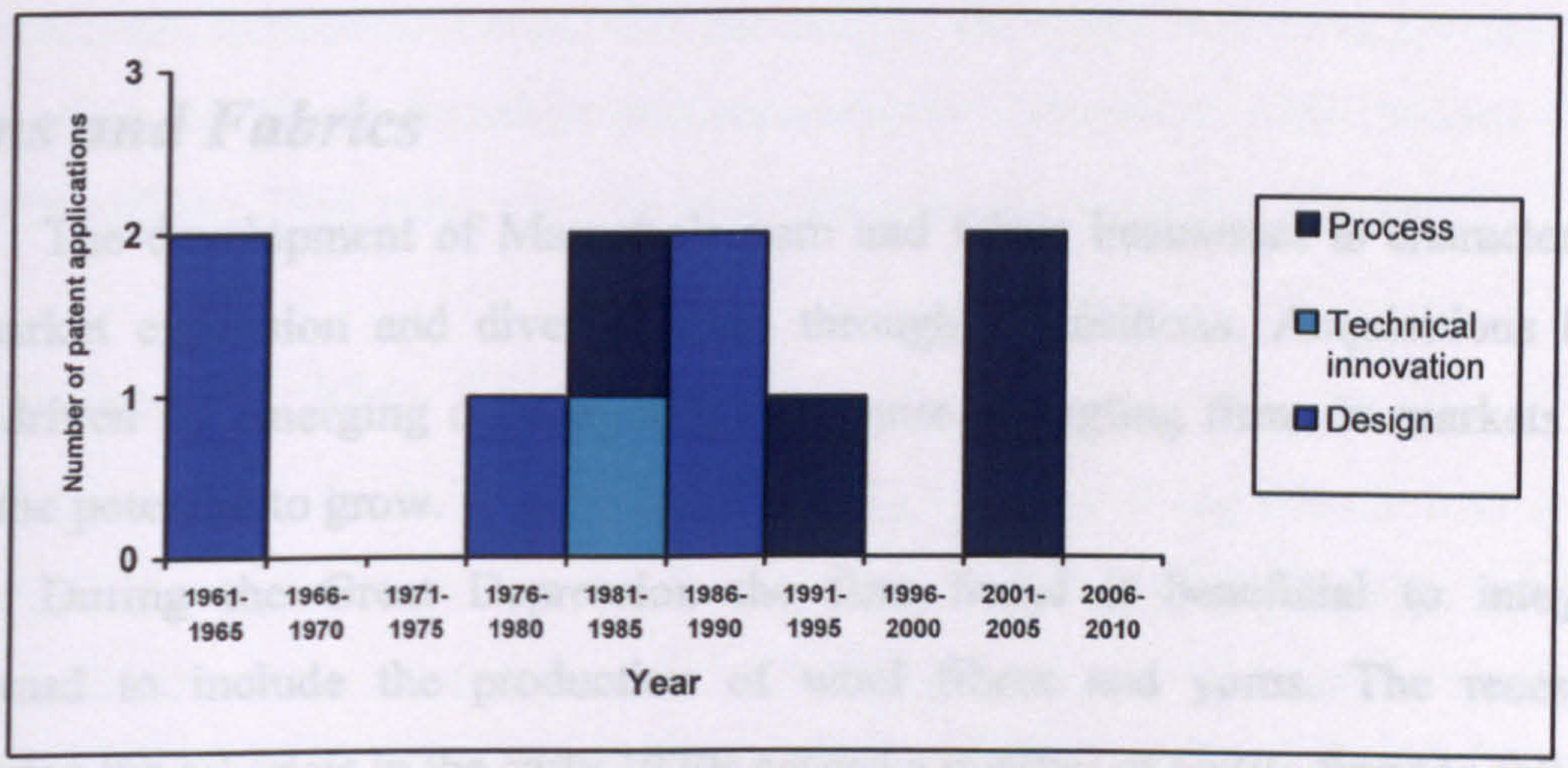

Figure 5-4.Patent portfolio of Marzotto
Source: European Patent Office

In this textile segment, R&D activities are significantly different from those in the technical textile market. The role of technology is focused on process technology to improve productivity, quality and flexibility. Customers' inputs are highly valued during the product development process. In fact, the firm dedicates teams to work together with customers in product development. In production, they combined old and new spinning and weaving techniques to create unique products. There is no plan on the horizon to adopt new knowledge to create new competencies and to add value to its customers. Meanwhile, their competitors such as Zegna made an attempt to adopt electronic textiles into its iJacket collection in 2007.

5.2.2 The Evolution of Competencies

The competence of the firm, that is, the production of high fashion textiles, has been preserved throughout its 174 years history. The firm, however, has not stood still. It has diversified its activities to include yarn manufacturing, finishing and cloth making through acquisitions. The extent of the diversification, however, is very limited. The market remains concentrated on the high-fashion market. The male fashion was the only market up to 2008 and only recently has the firm diversified into the female fashion market. This section analyses the process of diversification and divestment which has occurred within the firm. It will help us to understand the drivers behind the acquisitions and the impact of diversification on the firm's competitive advantage.

Yarns and Fabrics

The development of Marzotto's yarn and fabric businesses is characterised by market expansion and diversification through acquisitions. Acquisitions have been driven by emerging opportunities to acquire struggling firms in markets that have the potential to grow.

During the Great Depression the firm found it beneficial to integrate backward to include the production of wool fibres and yarns. The recession following the oil crisis in the early 1970s caused a number of textile firms to fall into financial difficulties. Under these circumstances, firms' values diminished and opened up opportunities for acquisitions. In 1985, Marzotto acquired the FinBasetti Group, one of the most important Italian textile groups. The purchase included a controlling interest in Linificio e Canapificio Nazionale, a linen yarn producer, and Mascioni, a leading textile printing and finishing company. In 1987, the firm acquired the state-owned Lanerossi Group, a woollen yarn and fabric manufacturer, by which it increased its total revenue by 72 per cent. This acquisition has made Marzotto the first fully integrated wool producer which encompassed the entire productions process from sheep rearing to suit making. Two years later the firm purchased LeBlan&Fils, a linen yarn producer from France, and this was followed by the acquisition of Lanificio Guabello, a woollen mill, in 1991.

In the 1990s, however, pressures from new foreign competition increased. This forced Marzotto to relocate production to low-cost countries. It opened a subsidiary linen factory, Filin in Tunisia in 1993. In 1994, it acquired a wool factory, Nova Mosilana, in Brno, Czech Republic to focus on combed textiles made of pure wool, as well as to build a bridge into the Eastern European market. The share of overseas production has increased and reached 50 percent of its wool production and 60-70 percent of its linen production in 2004.

The relocation of production forced the firm to discontinue a number of production facilities in Italy. The woollen combing in Mortara and finishing plants in Schio were closed in 2005 and 2006 respectively, while other parts of the operations were transferred to Nova Mosilana. Spinning and dyeing operations were transferred to the Czech Republic. Around 50 percent of the mid-level products are now produced in the Czech Republic and accounts for 70 million metre fabrics worth about €8 million. This rationalisation led to the loss of more than 600 jobs.

High-End Fashion Clothing

One of the fundamental factors that has played a significant role in the growth of the Italian high-end fashion industry is its close relationship with the textile manufacturers. Large textile manufacturers have financially *sponsored* apparel designers to develop and design clothing made from their fabrics since 1952. Marzotto began its relationship with fashion designers by sponsoring a number of fashion houses, such as Rivella and Pucci in 1952. But it was not until the 1970s the firm *integrated forward* to start its fashion clothing business. As to the majority of large textile firms in Italy, Marzotto exported its apparel collections to the US as part of the loan repayment programme to the US government in the 1970s as discussed earlier.

Intensified competition in consumer textiles and clothing, as well as the rise of the Italian luxury fashion industry encouraged Marzotto to gradually shift its clothing business from consumer clothing to upmarket fashion from the mid 1980s. The firm entered designer markets in 1986 by launching M. Missoni under a licensing agreement. A major turning point in this division came in 1991 with the acquisition of Hugo Boss, Germany's largest manufacturer of menswear. The acquisition promoted Marzotto as one of the major firms in the designer fashion market. The firm continued to expand its clothing brands throughout the 1990s, through licensing (Gianfranco Ferré Studio, GFF Gianfranco Ferré, Gianfranco Ferré Forma, M. Missoni, Marlboro Classic) and creating its own labels (UomoLebole, UL Trendy, Borgofiori, Marzotto Lab).

As with its yarn and fabric business, increased cost pressures in the clothing market forced Marzotto to relocate 40 per cent of its clothing production overseas from 1993. It had to shut one of its local clothing plants in 1993 and complete the purchase of a 90 percent ownership in Czechoslovakia's Nova Mosilana in 1994. In 2000, Marzotto purchased an 84.4 percent stake in Litekas and Calw, a Lithuanian woollen garment manufacturer. The acquisition permitted the firm to move part of its garment production to low-cost countries. However, intense competition from the Far East in more recent years has eroded the firm's profitability in all business units except the highest-end segment. It encouraged the firm to expand its high-end fashion business by acquiring Valentino in 2002 for €133.5 million. The firm was successful in the implementation of a revitalisation strategy for Valentino through the launch of a new label, Red, to capture emerging youth markets.

In 2005, the firm decided to demerge the clothing business. It was claimed that the complexity of managing two business sectors, each of which requires different management, marketing, and strategy forced the firm into the demerger. The new firm emanated from the demerger is named Valentino Fashion Group which incorporates the Marzotto's fashion brands including Hugo Boss and other licenses. Marzotto will remain focused on the high-end textile business.

After the demerger, Marzotto initiated a major restructuring, rationalisation, as well as expansion throughout 2005-2007. This was to improve the utilisation of production capacity, the integration of product ranges, and the efficiency of marketing and sales. It initiated a joint venture with Verzoletto to manufacture woollen yarns made of pure wool, acrylics blends, and carded knitwear. Marzotto believed that the joint venture would enable the firm to optimise its cost structure, improve its competitiveness and enhance its product portfolio. To enter the finest woollen fabric market Marzotto acquired Fratelli Tallia di Delfino, a very fine woollen fabric manufacturer in 2008. The acquisitions have made Marzotto the largest wool producer by volume in Europe.

5.2.3 Drivers of Change

The development of Marzotto shows that the firm has remained in the same business for the last 174 years although it now is on a far greater scale in terms of production, equipment, brands and numerous market segments. The dynamism of the firm has been driven by changes in the competitive environment, especially changes in (fashion) market demand and the emergence of low-cost competitors. Recent trends have shown that the customers are no longer willing to pay premium prices and instead demand fashionable designs at more affordable prices. As customers are its main source of information in product development the firm has put an established research strategy in place to examine changes in market demand through surveys and working with its major customers. The result provides the firm with customer feedback about the future trends in design and materials. Marzotto responds to the feedback with the development of new products exhibiting new designs, blends of fibres and finishing techniques.

Although customer demand is one of the important sources of innovation, relying heavily on this entails substantial risks for the firm's long-term existence (Hayes and Abernathy, 1980). Customers may know their present needs but they often do not have sufficient knowledge or vision about the trend in the distant future. Thus, a customer-driven strategy may be suitable for the short-term development programme but may not be sufficient for the long-term one. Relying on this strategy may lead the firm into short-termism. As discussed in Chapter 3, short-termism could lead firms to fall victim to the maturity-trap.

As mentioned earlier, the firm's main source of technical innovation is the adoption of more flexible equipment with higher productivity. Changes in technology which can improve the value of its products or facilitate the diversification of its competencies have been overlooked. Hayes and Abernathy (1980) suggest, however, that merely buying off-the-shelf equipment will not provide an edge for long-term competitiveness or solutions to long-term decline. Competitors can purchase the same technology and imitate other firms' products. As technology is not the differentiating factor, this will drive competition to efficiency and lower costs.

Indeed, counterfeit goods of high fashion brands have become an increasing problem for the fashion industry. For the clothing subsector, the high-street retailers can rapidly copy or imitate new fashion trends created by high-end fashion designers. In the accessory subsector, particularly handbags, counterfeit goods have become a very large business. More alarmingly, a portion of the high-end fashion customers have shifted to counterfeit products as the quality has significantly improved while the price is less than one tenth of that of the genuine products. This shows that competition in quality and design alone today cannot provide a sustainable competitive advantage. Therefore, Marzotto should redirect its business and find the market where it can achieve a long-term competitive advantage.

5.2.4 The Dynamic Capabilities of Marzotto

Marzotto is undoubtedly a responsive firm with a flexible organisational structure. Its ability to perform a number of acquisitions, divestment and the relocation of production to adapt to changing business environments has been its dynamic capabilities. The firm has conducted restructuring processes that involved the integration of new firms and the closure of uncompetitive plants without interrupting business activities. As a result, it has survived global economic downturn(s) in the past.

However, in today's harsher competitive environment and faster changes in market and technology than it was in the past such a capability may not be sufficient. As discussed in Chapter 1 and Chapter 4, a number of high-fashion firms have been struggling to survive and the relocation of production has become inevitable. Marzotto's responses which were heavily influenced by deep entrenched traditional values date back nearly two centuries may have a devastating result. The management cannot appreciate the importance of building new competencies or creating new markets away from, yet related to, their traditional competencies or markets. Instead, the firm believes that multi-brands and flexibility to produce different qualities of fabrics is the strategy to pursue in an uncertain business environment. Hayes and Abernathy (1980) argue, however, the concept of corporate portfolio which aims to balance the overall risks and returns has made managers to become averse to risk and the pursuit of short-term profitability much more 'desirable'.

The firm's heavy reliance on the high-end fashion market may have excluded it from new developments in the related (but distant) fields. For instance, a number of fashion designers have entered sport and outdoor apparel as the markets have become increasingly fashionable. They have started to use performance textiles in their sports lines. Those fashion houses have learned new knowledge related to performance textiles and may use it for future applications. The application of performance textiles in fashion products may foster the creation of new market niches. It was discussed in Chapter 4 that recent developments in multifunctional and smart textiles can be exploited by traditional textile manufacturers. Burlington Industries, for instance, integrated Phase Change Materials into its jumper collections to add more value to its customers.

This suggests that there are alternative routes that Marzotto could opt for to diversify its markets and capitalise from emerging markets and technologies. The firm's ability to diversify into non-mature markets is crucial for its long-term growth. As discussed earlier the high-end fashion market is not immune from the threat posed by low-cost competitors. In fact, a number of high-end fashion designers have produced their second line collections at more affordable prices to increase market penetration. If cost pressures continue to increase those fashion designers may have to once again redirect their strategies when they find theirs are no longer competitive.

5.2.5. Implications of the Maturity-Trap at the Firm Level

It appears that Marzotto is in danger of falling into the maturity-trap. The firm shows organisational rigidity and short-termism in their response to changing business conditions. The firm remains adamant that the high-end segment is immune from competition from low-cost countries. They do not consider that other firms from different countries may be able to provide similar quality at lower prices with larger financial resources. The experience of the Italian textile industry to penetrate high quality textile and clothing which ended the domination of France is a useful example to show that the high-end market can fall victim to lower-cost competitors.

Such an organisational inertia is a consequence of deeply-rooted practices and values (Sull, 2000). The firm uses the same strategy (diversification in similar markets), implements the same routines (acquisitions), develops cooperation with the same suppliers and believe in the same values that the quality associated with 'Made in Italy' label remains unchallenged. This behaviour may be liable if demand was stable but it is not. It is in fact dynamic and changes continuously.

Interestingly, as mentioned earlier, the firm recognises that the business environment is changing faster than ever as a consequence of new entrants, changing technologies and shifting market preferences. The power within the supply chain has moved from designers to retailers since 2000. The rules of the game that link manufacturers, fashion houses and retailers have also changed. Large retailers which have the power to purchase products in large volume and move large orders from Europe to Asia and to Africa have put greater pressure on textile manufacturers to reduce prices. Manufacturers are forced to work with short-term cost reduction as their main driving force than long-term growth. In spite of the recognition of the problem the firm insists it must still follow the same strategy. It appears that Marzotto suffers from short-termism and overlooks the importance to look for new routes for its long-term growth.

This has parallels with the Lancashire cotton industry. As discussed in Chapter 3 the Lancashire firms suffered from short-termism because of their deeply entrenched business practices. In the face of a changing business environment management was unable or unwilling to fundamentally change their business practices. A number of factors that contributed to this were limited knowledge in different business areas, deeply embedded routines or procedures, low diversity of knowledge and skills and large infrastructure. These are also the underlying factors that have put Marzotto into a serious danger of falling into the maturity-trap. Under these circumstances, the management maintained the status quo at the expense of long-term competitiveness (David, 1986). The only way out of this predicament is through collective action which is a huge mountain to climb given the intensity of the competition among the firms.

Marzotto needs entrepreneurial management that can break down the barriers that impede radical change. They need to implement an innovative corporate culture to escape from the maturity-trap. Given the history of Marzotto, change will not come easily. The firm needs a strong leader to turn the firm around. The leader has to have the capability to broaden the firm's competencies and anticipate future trends that may have an effect on its competitiveness. The theory being this should lead to the development of new capabilities that permits greater diversification. A narrow market focus makes it vulnerable to changes in the external environment. However, these changes have to be complemented with new organisational capabilities.

Courtaulds shows that diversification often requires different corporate strategies. Implementing the same strategy in a different business environments or different markets can lead to organisational inertia.

5.3 Conclusion

Marzotto illustrates the behaviour of a firm falling into the maturity-trap. It shows that although the firm has recognised the significance of external changes and admitted that such change occurs at a faster rate than ever before its response is to continue with its old strategies. Such a response is based on the assumption that the change is temporary so that continue with what they know best is the best answer for the current problems. It ignores the fact that the recent development indicates that the change could be permanent. There is no plan on the horizon for the development of new competencies and new products away from its traditional markets, despite an uncertain future. This behaviour parallels to that of the Lancashire firms which led to their decline.

It is argued that although the response may be necessary to satisfy the current needs of its customers it fails to address issues related to its long-term competitiveness. Moving up to the higher market segment may help it to move away from cost competition. However, as history has shown it cannot stop other low-cost competitors to *catch up* with in quality. Consequently, in the long-run cost competition will become inevitable. This strategy, therefore, is a 'temporary' than a long-term solution. The firm appears to suffer from serious *organisational inertia.* Business decisions to avoid more risky, longer term business at the expense of potential emerging markets for long-term growth is a result of *short-termism.* This behaviour has become a disease that has affected the management and caused lock-in to the existing business and structure.

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6

Royal Ten Cate: De-maturity and Radical Change

6.1 Introduction

The size of the Dutch textile industry is smaller than those of its main European competitors such as Italy, UK, Germany and France. Its revenue was less than three per cent of that of the Italian textile industry in 2007 (€3.6 billion, down from 4.5 billion in 2000). In Europe, its revenue accounted for only two percent of the total revenue of the EU textile and clothing sector in 2004 while the employment represented 1.3 per cent. Whilst it may be relatively small in size, the Dutch textile industry is arguably one of the most successful with one the highest rates of productivity in the EU. Compared to the European leader, Italy, its rates of productivity has been significantly higher over the last decade. In 2002, Dutch productivity was 29 per cent higher and in 2003 it increased to 42 per cent, before declining to 28 per cent in 2004, despite the fact that the Netherlands is one of the highest-wage economies in Europe[1] (Eurostat Publication, 2005, 2006 and 2007). According to one report on the innovative performance of the European textile industry (2000-2003), the Netherlands emerged as the overall leader when measured in terms of patents and total factor productivity (Marin, *et al.*, 2008).

The structure of the industry is a result of a long process of industrial transformation which began in the early 1960s following a severe decline after World War II. As with Britain, cotton textile trading was one of the largest export earners for the country's economy during the 19th century. The primary market was

[1] The Netherlands was number two after Luxembourg in terms of average wage in the EU textile industry in 2003 (Eurostat)

high-volume, low value-added cotton fabric exports to its former colonies. The emergence of low cost competitors, particularly Japan and India in the 1930s and the independence of the former colonies in 1949 led to a severe loss of market share (van der Eng, 1998). In response to this serious situation, there was a wave of mergers and acquisitions after 1956 as the industry consolidated, and this was followed after 1963 by the relocation of production to reduce costs. Following these changes, the industry witnessed a severe loss of employment and the industry emerged as the most concentrated in the EU by 1965[2]. The loss of employment was the most extensive of any countries in Western Europe (van Geenhuizen and van der Knaap, 1994).

Despite the loss of the competitive advantage and the change in market conditions, the majority of firms attempted to defend their traditional businesses and eschewed the opportunities to develop new markets. It appears that its major reliance on cheap cotton product markets for the former colonies and highly concentrated industrial structure caused inflexibility and inertia. These were, in fact, also the primary factors of the demise of the British cotton industry as previously discussed in Chapter 3. The industry took a similar approach to that of Britain by opting for mergers and acquisitions than the relocation of production in response to the changing environment. It is argued here that the Dutch textile industry fell into the maturity trap, along with its counterpart in Britain.

Against the considerable industrial decline, a small number of innovative traditional textile manufacturers have re-emerged to become high-technology textile manufacturers. Those firms produce a wide range of higher value added textiles in a number of sectors such as the military, aerospace, automotive and medical. They have concentrated on niche markets and produced new products based on new materials. The Dutch technical textile sector is now in a strong competitive position both within Europe and globally. Evidence of its prowess can be found in the fact that Royal Ten Cate is the world leader in geotextiles and pioneered the use of synthetic fibres in the market through its one of its subsidiaries, Nicolon (John, 1987). The firm has also emerged as a prominent armour producer in Europe. Other

[2] By the 1980s, Britain replaced the Netherlands as the most concentrated textile industry in the EU, whereas Italy and Germany were the least. Currently, the Netherlands stand somewhere in between the two extremes (Euratex Bulletin, 2000-2003).

firms such as Desso-DLW, together with Ten Cate, are among the major global suppliers of synthetic grass. Gamma Holding, a large cotton textile manufacturer up to the 1960s, has emerged as a prominent figure in the belting and mattress ticking markets. Eurocarbon has modified its competence in the manufacture of braided fabrics for the shoe lace market to offer solutions for industrial markets made of glass, carbon and aramid fibres. Furthermore, the Dutch carpet industry is the second largest in Europe after Belgium and the third in the world behind Belgium and the US. It shows that those firms have managed to shift their businesses to produce products in demand for markets in which they are competitive.

These firms have undertaken a *strategic redirection* (Doz and Prahalad, 1988) by shifting their core competence away from manufacturing traditional textiles to developing high value added textiles. In other words, they have initiated the process of de-maturity and bypassed the maturity-trap by which those firms regain their competitiveness. A strategic change of this nature involves a radical transformation of both strategic[3] and organisational[4] aspects of firms so they are configured until completely in line with each other. By initiating the process of de-maturity firms have to be aware that they will often have to restructure, change their perspectives of their markets and invest heavily to modify and broaden their knowledge base. Therefore, compatibility between the strategic and organisational aspects of the firm, or 'internal fit', appears to be absolutely critical to improve the likelihood of success in any form of strategic redirection.

This chapter seeks to contribute to the development of the theory of innovative enterprises by analysing the attempts made by a mature firm to initiate the process of de-maturity and bypass the maturity trap. The case study of Ten Cate vividly illustrates the way in which a mature textile firm with a very long tradition can radically transform itself over an extensive period of time. This was achieved through *the creation of a series of new competencies* and *capabilities* that have enabled it to adapt to changing technology and market trends and to overcome organisational inertia. It is argued here that the creation of new competencies and capabilities is fostered by a radical change in its knowledge-base and know-how through the adoption of new knowledge and technologies, the development of new

[3] The strategic aspects include technology-product-market portfolio.
[4] Organisational aspects refer to the firm's process and structure,

products and access to new markets. By initiating the process of de-maturity the firm also had to restructure its organisation, change its strategic perspectives of the markets and invest heavily to renew and broaden their resource base. All of those changes have to achieve internal fit as discussed earlier.

De-maturity, however, is only a beginning of a continuous process of change. It has to be followed up with new investment to continuously create new capabilities and competencies and reconfigure the resource-base[5] to improve the 'evolutionary fitness' of the firm. This has to be complemented with the ability of the management to strategically select the areas of new investments which can generate new paths of growth. These are in fact the essence of the dynamic capabilities of the firm which have been identified as the foundation of sustainable competitiveness (Helfat, *et al.*, 2007, Teece, *et al.*, 1997).

The key issues will be addressed by this case study are the factors that drive change, the process or mechanism to create new competencies and the capability to continuously initiate and manage change. These improve our understanding of the foundations of the sustainable competitiveness of the firm. In what follows, the periods of strategic redirection occurred in Ten Cate and the nature of the change is outlined. The third section of the chapter describes the firm's strategy to undertake such changes and its pathways to generate new knowledge and reconfigure its resource-base. These mechanisms have radically changed the direction of the firm and fostered to bypass the maturity-trap. In section four, the detailed process of new knowledge generation and the factors that contribute to the process and relationships among them is discussed. The implication of this for the evolution of competencies and capabilities of the firm and their impact on de-maturity are elaborated on.

6.2 Royal Ten Cate

Royal (Koninklijke, in Dutch) Ten Cate ('Ten Cate') is one of the world's leading producers of technical textiles. This publicly quoted firm based in Almelo is

[5] We use the definition of resource base by Helfat et al. (2007) which refers to ......"tangible, intangible, and human assets (or resources) as well as capabilities which the organization owns, controls, or has access to on a preferential basis.........we consider capabilities to be resources in the most general sense of the word. By this we mean simply that resources are something that organization can draw upon to accomplish its aims" (Heflat, et al. (2007, p. 4).

the oldest Dutch industrial firm whose history can be traced back to 1766. The firm is the combination of a merger between two textile firms, H. Ten Cate Hzn & Co of Almelo and Koninklijke Stoomweverij, NV (KSW) of Nijverdal, in 1957. Throughout its 243 year history, Ten Cate has transformed its business away from its original roots and against the main trend of firms in the industry. From manufacturing cotton fabrics for traditional textile markets, Ten Cate has emerged as a leading firm in high performance textiles, supplying a diverse range of global (niche) markets derived from advanced and functional materials (Figure 6-1). In 2008 the firm surpassed €1 billion turnover for the first time in its history and employs over 4000 people.

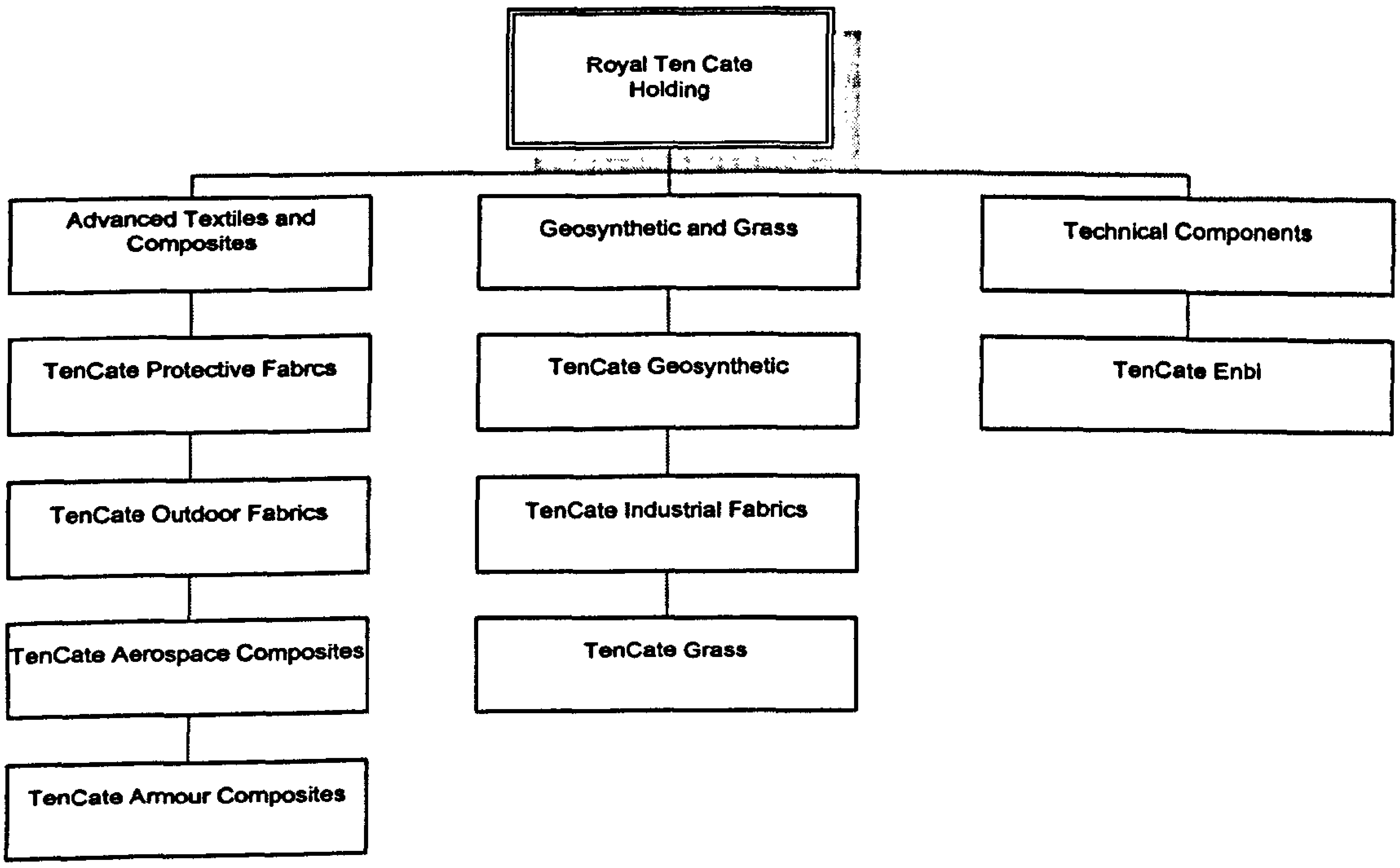

Figure 6-1. Current organisational structure
Source: Annual Report, 2008

The current organisational structure is decentralised with a mere 30 people working for the Holding Company whereas the rest work for 55 operating firms (wholly or partly owned subsidiaries) that are managed within three sectors.

The firm's transformation has only been achieved by going through a series of transitions characterised by four distinct periods as shown in Figure 6-2. The first strategic change occurred in 1841 in order to expand its market to the Dutch former colonies through the acquisition of a firm which had long been the supplier to the market. Following the loss of its market share in the colonies the firm undertook the second strategic redirection to shift the main market from the former colonies to the domestic and the European markets through a series of mergers and acquisitions. Throughout the first three periods, the adoption of new technology was not as important as market expansion and restructuring. The fourth strategic change which began in the early 1970s provided the foundation for the development of new capabilities to foster continuous change. During this period, the firm built new competencies away from its traditional roots primarily through acquisitions, divestments, reorganisations and R&D. Later, however, was not as crucial as firm acquisitions. It was probably due to its lack of 'capacity' to conduct R&D in new markets. The firm learned and built up its R&D capabilities from the acquired firms. In the subsequent period of strategic change, R&D, particularly in advanced materials has become central in the process of new competence development, together with acquisitions. In fact, in 2004, the firm announced its attempts to shift its core competence from the manufacturer of technical textiles to the developer and producer of functional materials. Such a shift was combined with the modification of its core growth markets to protective fabrics, aerospace composites, antiballistic materials, artificial grass and geosynthetics. The firm therefore is currently undergoing another transition process.

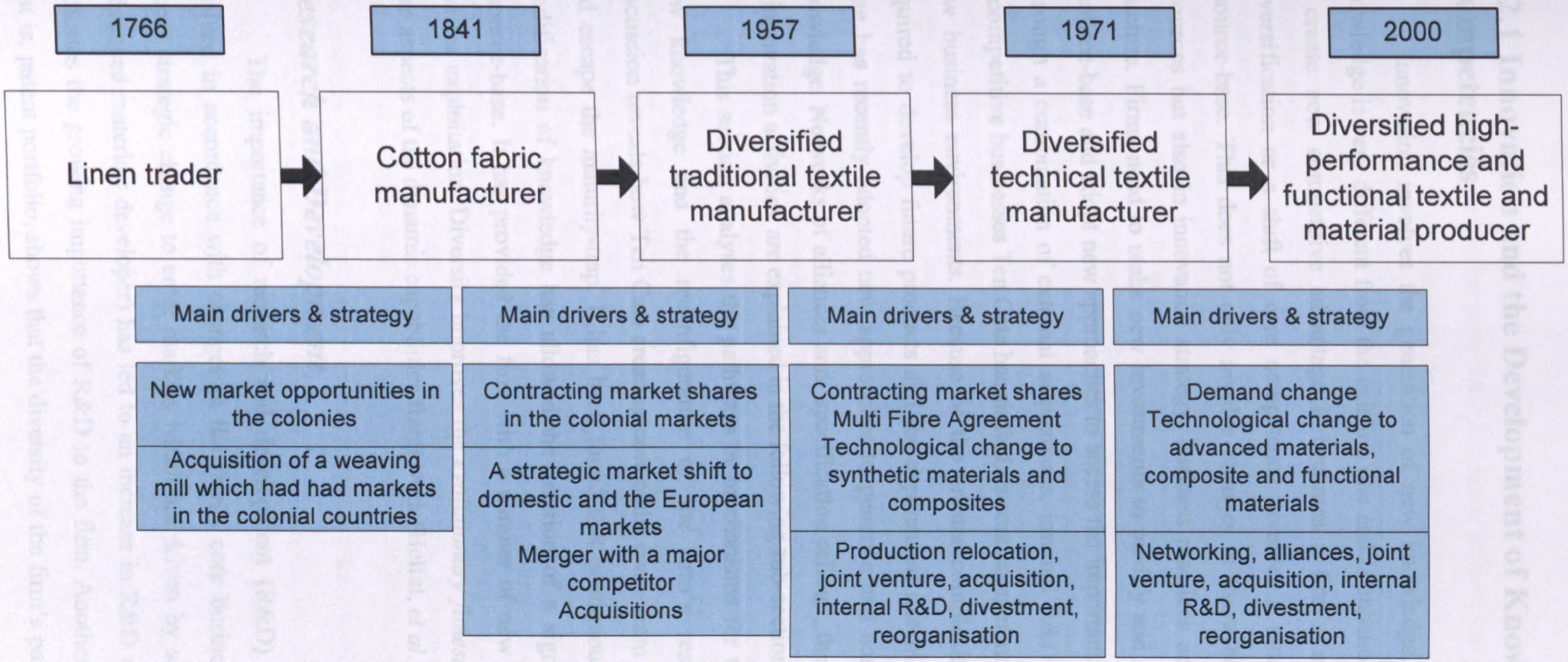

Figure 6-2. Four periods of strategic redirection of Ten Cate
Source: Author

6.2.1 Innovation and the Development of Knowledge and Competencies

Innovation involves the generation of new knowledge. When the new knowledge is very different from the existing one and is enhanced and expanded to create new competitive advantage it becomes a firm's new competence. Diversification or a shift of core competence involves a modification of the resource-base. This does not only involve changes in know-how and physical resources but also in innovation strategy, business practices and organisational structure. Firms need to make new investments to modify and reconfigure their resource-base and adopt new approaches to access the important new knowledge. Through a combination of external acquisitions, internal R&D and disposal of uncompetitive businesses Ten Cate has shifted its core competencies to respond to new business environments. Because of the greater complexity of knowledge required to develop future products and the exponential rise in R&D costs Ten Cate has recently adopted new approaches to generate and commercialise new knowledge. Networks of alliances and 'specification selling', the new approaches in innovation activities, are explained in the following sub-sections.

This section analyses the pathways or mechanisms for the generation of new knowledge and the reconfiguration of the firm's resource-base. The discussion reveals how Ten Cate creating new paths away from its original roots and escape the maturity-trap. It has been found that continuous generation and modification of knowledge has allowed the creation of a significantly diverse resource-base. It has provided the firm with a number of new alternative paths ripe for exploitation. Diversity improves the *evolutionary fitness* of the firm, the core aspects of the dynamic capabilities framework (Helfat, *et al.*, 2007).

Research and Development

The importance of research and development (R&D) to the firm has evolved in accordance with changes in the firm's core businesses. The firm's recent strategic change to enter markets which are driven by scientific research (advanced materials developer) has led to an increase in R&D expenditure. This indicates the growing importance of R&D to the firm. Another R&D indicator, that is, patent portfolio, shows that the diversity of the firm's patent portfolio has increased considerably since its entry into high-value added textile markets (Figure 6-3). Compared to the past, R&D has more recently played a central role in the firm's ability to generate new knowledge to support its strategic redirection.

Prior to 1980, technological innovation was undertaken to improve production efficiency and cost reduction. Although the firm started its diversification in the 1970s, their core business remained traditional textiles of a very standard nature and these were heavily exposed to price competition. In such a market, patents played virtually no role to build up the competitiveness of the firm than firm acquisitions to achieve economies of scale. As a consequence, the firm had no major patent portfolio (Figure 6-3). After 1980 with the diversification strategy in full swing, patents became much more important and were generated through heavy investment in R&D. Patents have become much more of strategic value to the firm than ever before. As illustrated in Figure 6-3, the diversity of patent has increased significantly.

Between 1980-1990, patents in advanced textiles (protective fabrics) and composites dominated the patent portfolio. Between 1990-1995, the number of patents dropped significantly due to the firm's focus on the consumer plastics business. In fact, in 1994 plastic based products accounted for 80 per cent of the firm's turnover. Technical development in this market was stagnant as development was primarily directed at gaining economies of scale. The firm emphasised its growth strategy through market expansion and acquisitions. The situation changed in 1996 as new competitors from low-cost countries emerged which forced the firm to reduce its activities in the consumer plastics market. The firm shifted towards the intensification of technological development in protective fabrics and artificial grass and the creation of new competencies in armour composites and digital textile finishing processes. The patent portfolio increased and diversity widened. The activity in the consumer plastic market was shifted to plastic components for printers whose competition required greater product/technological development than cost efficiency. This confirms Cohen and Levinthal's (1990) contention where R&D improves the absorptive capacity of the firm and helps it to recognise new opportunities in emerging fields and encourages investments.

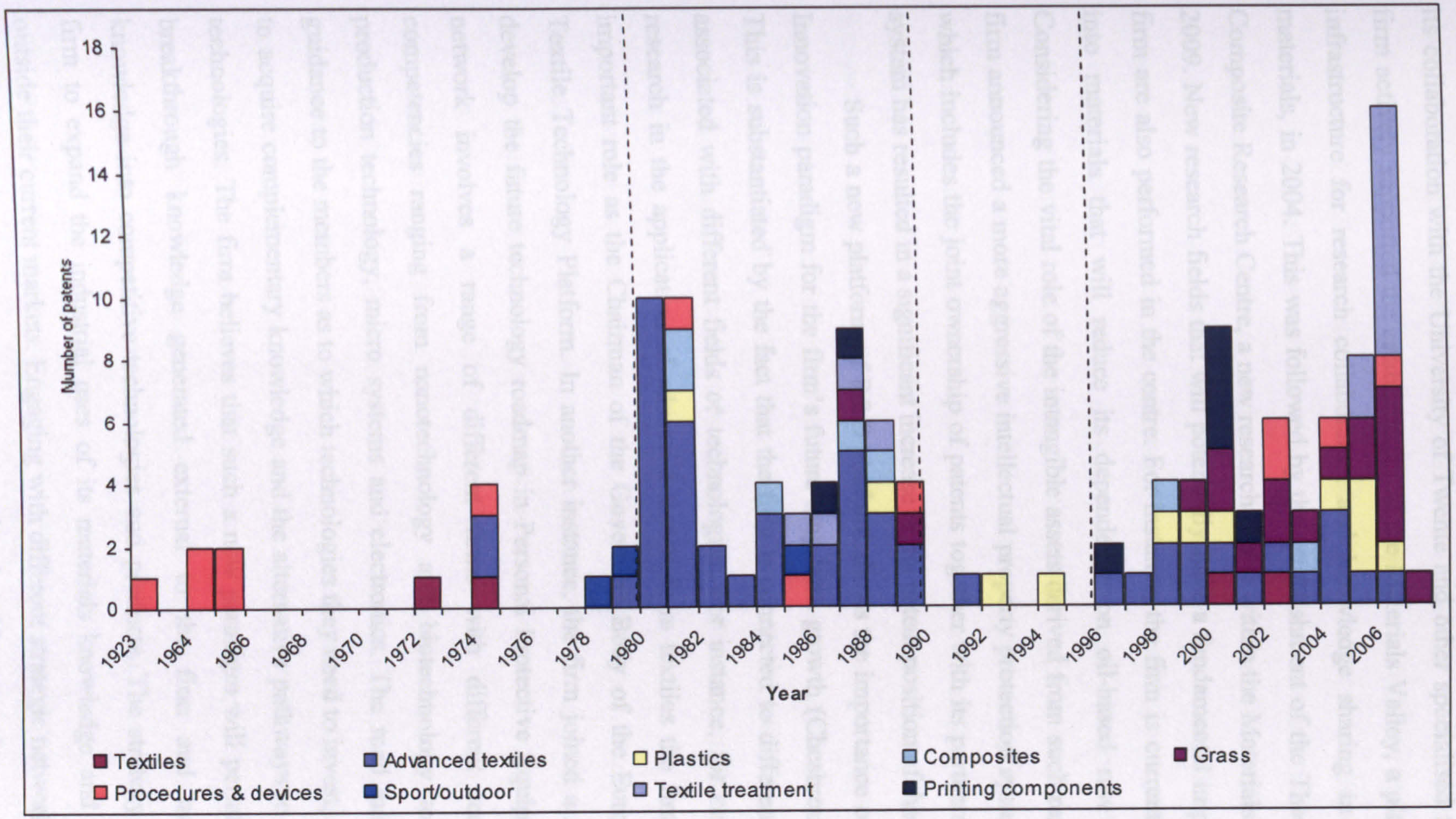

Figure 6-3. Patent portfolio based on the year of publication
Source: European Patent Office

Following the strategic redirection in 2004 which signified its greater commitment to long-term scientific research the firm has significantly increased its collaboration with the University of Twente and other specialised firms. The firm actively supported the establishment of the Materials Valley, a platform and infrastructure for research collaboration and knowledge sharing in advanced materials, in 2004. This was followed by the establishment of the Thermoplastic Composite Research Centre, a new research centre within the Materials Valley on 2009. New research fields that will potentially have a fundamental impact on the firm are also performed in the centre. For instance, the firm is currently looking into materials that will reduce its dependence on oil-based raw materials. Considering the vital role of the intangible assets derived from such research, the firm announced a more aggressive intellectual property protection system in 2004 which includes the joint ownership of patents together with its partners. The new system has resulted in a significant increase in the patent position of the firm.

Such a new platform of R&D platform shows the importance of the Open Innovation paradigm for the firm's future long-term growth (Chesbrough, 2006). This is substantiated by the fact that the firm is connected to different networks associated with different fields or technologies. For instance, for collaborative research in the application of advanced materials in textiles the firm plays an important role as the Chairman of the Governing Body of the European New Textile Technology Platform. In another instance, the firm joined a network to develop the future technology roadmap in Personal Protective Equipment. This network involves a range of different firms with different technological competencies ranging from nanotechnology and biotechnology to advanced production technology, micro systems and electronics. The road map provides guidance to the members as to which technologies they need to invest, the method to acquire complementary knowledge and the alternative pathways to exploit the technologies. The firm believes that such a new paradigm will permit access to breakthrough knowledge generated external to the firm and translate the knowledge into competitive technologies and products. The strategy allows the firm to expand the industrial uses of its materials knowledge and technology outside their current markets. Engaging with different strategic networks helps the firm to reduce the uncertainties associated with emerging markets and technologies. Networks allow some degree of control over an uncertain environment (Mattsson, 1988), avoid dependency on one particular emerging technology and reduce the risk of failure due to the high level of uncertainty of the rate and direction of new technologies (Rosenberg, 1996).

The period between 1980-2004 appears to be critical in the firm's strategic redirection. The first milestone indicated a move away from short-term cost reduction to mid-term new product development and diversification. This resulted in the development of diverse products derived from materials and technologies that were new to the firm. The adoption of fibre glass and composites for protective clothing, nylon and polypropylene for geotextiles and polypropylene for carpet backings are a few examples. The second milestone marked the fundamental shift towards long-term R&D and the open innovation paradigm. This change advanced the firm's capability to develop high valued added products derived from R&D resulted in high value added, high performance products including composites for body and vehicle armour and synthetic grass. Expenditure on R&D has increased significantly since 2005[6]. In 2006 the expenditure increased from €5.8 million in 2005 to €8.1 million. In 2007, the figure increased to €8.2 million before declining in 2008 to €7.9 million. These figures also include government funding which totalled €8.6 million in the past five years.

Expenditure on R&D reached a peak in 2007 when it hit 1 per cent of turnover[7]. The level of expenditure is comparable with one of its competitors, Gamma Holding, but was higher than the average rate in the country which was only 0.6 per cent between 2000-2003. Germany and Belgium, the leaders in technical textiles in Europe, however, have a significantly higher rate which reached 1.2 per cent (Marin *et al.*, 2008). It indicates that although Ten Cate is considered as one of the most innovative textile firms in the Netherlands its European competitors appear to be more aggressive in R&D. As we shall see in the next chapter, Freudenberg's R&D expenditure reached 3.8 per cent of its turnover in 2008. This was perhaps due to Ten Cate's recent large investment in acquisitions to generate new knowledge. However, the sustainability of

[6] The firm's accounting system prior to 2005 did not show R&D expenditure as a separate cost posting from personnel and operating costs. Consequently, the precise amount of expenditure can be presented.
[7] The R&D expenditure as the percentage of turnover between 2008-2005 was 0.7, 0.9, 1 and 0.8 per cent respectively.

acquisitions as a means to generate new knowledge in this fast-changing environment is questionable. In particular as the firm aims at leadership in technological development, the knowledge it requires may not be available in the market. Therefore, Ten Cate may need to improve their scientific and technological capacity through R&D to compete at the global level in the future.

Acquisition of External Knowledge

As discussed earlier, the firm has developed an established capability in acquisitions as a means to broaden its strategic knowledge portfolio. In fact, this was established long prior to the development of its R&D capacity. The firm called this 'buy-and-build' strategy. The strategy focuses on building and strengthening its strategic resource-base through acquisitions of firms (including joint ventures). Synergies and complementarities with its technology portfolio to encourage growth are two factors that determine acquisitions. Indeed, Teece (2007) suggests that acquisitions should consider co-specialisation and complementarities between the resource-base of the firm and of the target firms. This allows the firm to generate idiosyncratic new knowledge. The firm has regularly modified its resource-base through acquisitions and divestments although it appears that the 1980s and 2000s are the periods during which it was used intensively. This corresponds to the periods of the firm's strategic redirection (Figure 6-2). Therefore, the firm uses acquisitions as one of the primary means to fundamentally change its resource-base.

To complement the R&D and buy-and-build strategy, the firm developed a 'fix-it-exit' strategy to balance its business portfolio. The strategy involves attempts to improve the performance of businesses that no longer fit with the current core markets before being offered for sale. R&D, buy-and-build and fix-it-exit strategies allow the modification and reconfiguration of resources and asset positions of the firm. This is argued by Teece *et al.* (1997) as the underlying factors that underpin the long-term competitiveness of firms operating in an environment of rapid technological change. The strategies therefore suggest continuous change and diversity of resources allow it to develop a broad technology-product-market portfolio believed to be beneficial in a rapidly changing environment. It has been argued that continuous change and a diversity of resources help the firm to initiate the process of de-maturity and bypass the maturity-trap. They help to promote agility, reduce inertia and improve responsiveness or evolutionary fitness.

Such a strategy however requires adequate (often large) financial resources, the persistent attention of the top management and capabilities to integrate the new organisations into the existing systems (Vermeulen and Barkema, 2001). Helfat *et al.* (2007) suggest that gains from acquisitions can only be appropriated by firms that possess the resources and capabilities to allow them to exploit the acquired assets. Therefore, in addition to the three factors above firms have to have the capability to generate 'unique' knowledge from the acquired and existing knowledge to create new competitive advantage.

The firm has certainly built these capabilities over time. Learning from the evolution of Ten Cate, it is evident that acquisitions are not necessarily detrimental to the performance of the firms involved as it has been widely believed (Ravenscraft and Scherer, 1987). Although it is true that Ten Cate had to sell a number of its acquired firms, it was undertaken to maintain its evolutionary fitness. In other words, divestment of businesses that were no longer in line with its new direction or losing their competitive advantage due to market saturation is one of the firm's strategic actions. In fact, acquisitions and divestments provided the firm with an organisational dynamic capability, that is, divestment-based capabilities to help the implementation of fix it-exit strategy. This capability has rarely been discussed in the literature of dynamic capabilities.

Management of Innovation

In Ten Cate, the implementation of the above strategies is guided by the value chain management business model. The business model is developed to provide general guidance for all departments on the manner in which businesses should be run (Figure 6-4). The business model comprises of four cornerstones and the linkages among them. *Innovation* is the core value of the firm which has been built up since the 1970s. It is undertaken to fulfil latent needs of current and potential costumers through *product differentiation or specialities*, as well as to improve the efficiency of the production process (*cost reduction*).

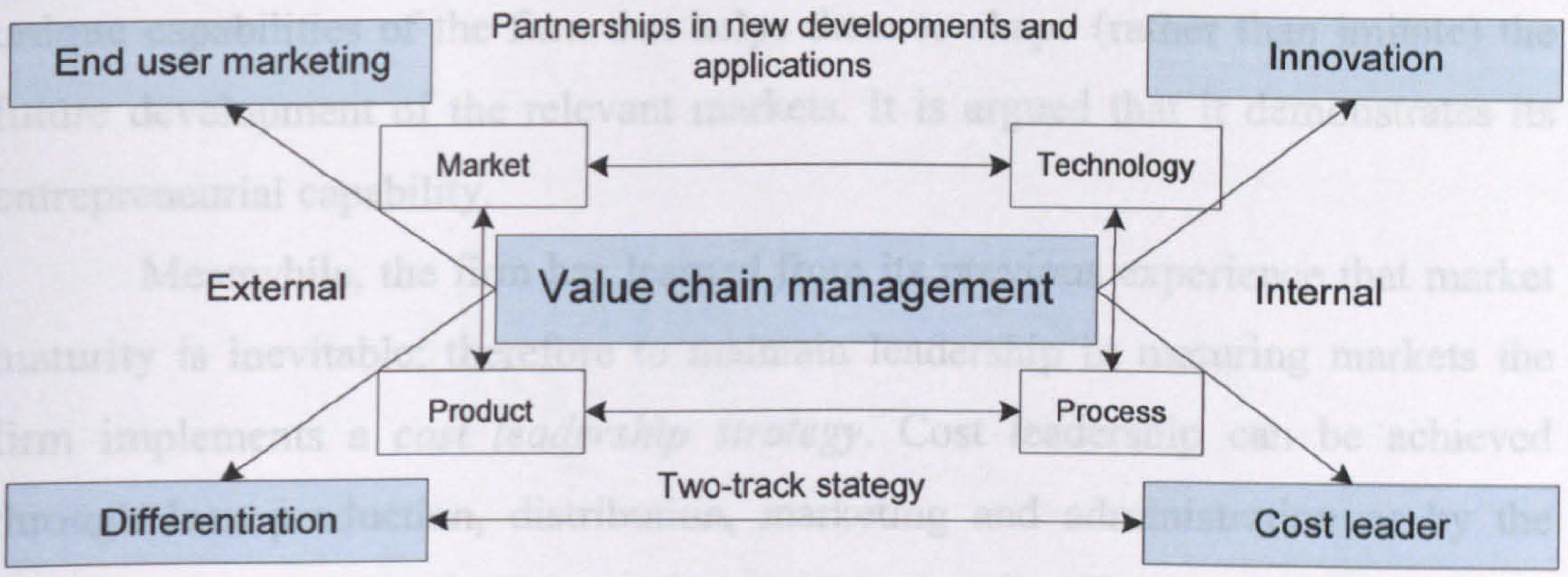

Figure 6-4. Value chain management
Source: Annual Report, 2008

This two-track strategy is in fact the implementation of product life cycle management. Ten Cate is aware that emerging textile producing countries, particularly China and India, have the ability to catch up with the performance of the Western manufacturers in high-technology textiles, with an advantage of significantly lower costs. The availability of the latest technologies in the market, the mobility of human resources and China's rapid-growing economy complemented with lower labour costs are amongst the factors that can contribute to the rapid catch-up. As a response, firms in developed countries have to continuously create new knowledge to provide better solutions for existing and new problems. Such a condition puts greater pressures on the product life cycle which has shortened rapidly in recent years. Consequently, the time available to sell new products and recover new investments has shrunk considerably.

Under such circumstances, Ten Cate has to possess cutting edge technical capacities, a diverse knowledge-base and the capabilities to foresee the trend in technology and *the requirements of the end users* ahead of its competitors. To shorten the development process the firm develops new specifications together with its customers. In many cases, the firm proactively develops new specifications and persuades the end customers in the value chain (not only their immediate customers) to adopt the new solutions. Such a proactive new product development strategy is referred to 'specification selling'. This practice brings about new relationships between suppliers and customers beyond the traditional practice. This new relationship requires suppliers to have the capability to read the future needs of the end users rather than only concern itself with the requirements of their immediate customers. Specification selling is claimed to be one of the unique capabilities of the firm that helps them to shape (rather than imitate) the future development of the relevant markets. It is argued that it demonstrates its entrepreneurial capability.

Meanwhile, the firm has learned from its previous experience that market maturity is inevitable; therefore to maintain leadership in maturing markets the firm implements a *cost leadership strategy*. Cost leadership can be achieved through lean production, distribution, marketing and administration or by the transfer of production facilities to lower cost countries. For instance, the market for outdoor fabrics in Europe and US has become saturated in recent years which forced the firm to implement a cost-leadership strategy. Due to the growth of the Asian markets, the cost-leadership strategy was implemented through the relocation of production to China. It helps the firm to work on tighter margins and benefits from economies of scale. The remaining assets in Europe are used to pursue the development of military markets (military tents and uniforms) where competition is based on product performance. This shows that the firm possesses a certain level of flexibility to allow the transfer or reuse of resources for different activities. The implementation of the innovation strategy is depicted in Figure 6-5.

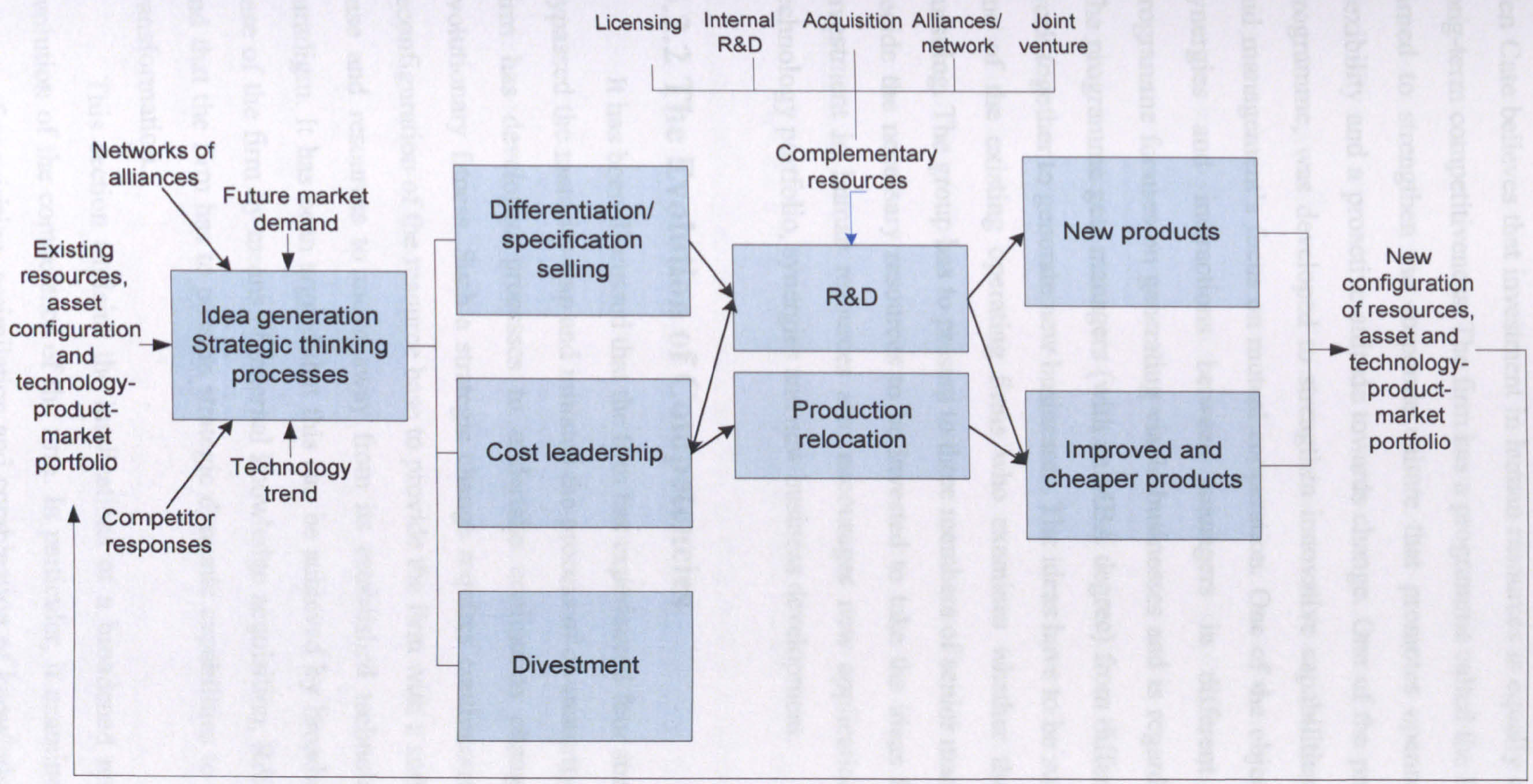

Figure 6-5. Process of innovation-modification, expansion and reconfiguration of the resource-base
Source: Author

In addition to innovations which results in the configuration of resource-base, Ten Cate believes that investment in human resources is equally crucial to maintain long-term competitiveness. The firm has a programme called the People Programme aimed to strengthen the corporate culture that promotes openness to new ideas, flexibility and a proactive attitude towards change. One of the programmes, Active Programme, was developed to strengthen innovative capabilities, entrepreneurship and management's focus on mutual cooperation. One of the objectives is to initiate synergies and interactions between managers in different businesses. The programme focuses on generating viable businesses and is regarded as a 'seedbed'. The programme gets managers (with an MBA degree) from different subsidiaries to work together to generate new businesses. The ideas have to be supported by at least one of the existing operating firms who examines whether the ideas are worth pursuing. The group has to present to three members of senior management who will decide the necessary resources to be invested to take the ideas forward. Thus, the investment in human resources also encourages new applications of the existing technology portfolio, synergies and new business development.

6.2.2 The Evolution of Competencies

It has been discussed that the firm has experienced four strategic redirections, bypassed the maturity-trap and initiated the process of de-maturity. Furthermore, the firm has developed processes to undertake continuous change to improve its evolutionary fitness. Such a strategic change requires continuous modification and reconfiguration of the resource base to provide the firm with a sufficient knowledge-base and resources to move away from its established technological and market paradigm. It has been argued that this can be achieved by broadening the resource-base of the firm by means of external knowledge acquisition, R&D, and divestment and that the firm has to possess strategic dynamic capabilities to orchestrate such a transformation.

This section explains the implications of a broadened resource-base to the evolution of the competence of the firm. In particular, it examines the strategy and process of acquisition, assimilation and combination of knowledge to generate new knowledge and the impact of such processes on the transition of the firm's technology and competence. The emphasis is on the evolution of the business groups that have major roles in driving the transition towards high-performance textiles (advanced composites, geotextiles and geosynthetics, protective fabrics, artificial grass and digital inkjet printing).

It has been identified that the adoption of new materials technologies has been the major driver in the evolution of its competence. The firm has continuously adopted and developed materials with distinctive characteristics and added values as a means to create a competitive advantage in all markets it is active in. This has broadened the diversity of its knowledge-base and market and product portfolio. It is revealed that the foundation of its newly acquired competence in materials development was developed from its traditional competence in the manufacture of traditional textiles. The traditional competence has been radically enhanced and combined with different technological domains to generate the new competence.

Traditional Textiles

Ten Cate's first business was linen fabric trading after which it expanded to the manufacture of cotton fabrics in 1841 by means of an acquisition. Following the merger with KSW of Nijverdal in 1957 the firm diversified its business into several different markets including fabrics for fashion and household markets. However, as the firm's competitiveness in the various markets started to decline in the 1980s and the business was finally abandoned in the 1990s.

Advanced Composites

With the firm's traditional business was on the verge of decline, an opportunity appeared in 1961 to take a ten percent stake in Pierre Genin & Cie, a French woven glass producer. Interestingly, the opportunity arrived not as a result of a deliberate attempt at diversification but came about by accident as the firm was invited by one of its partners, JP Stevens, who planned to broaden its business into fire resistant fabrics made of glass fibres for the European market. Although Ten Cate had no knowledge of the corresponding technology and business, its *reputation* as the largest textile firm in the Netherlands earned the trust from its partner. This was the firm's first alliance in the field that was not related to its traditional core business.

For Ten Cate, a participation as one of the shareholders in a firm whose competence is very different from its traditional competence may be the most efficient approach to make rapid entry into a new market. By 1963 Ten Cate had set up a number of looms in place for the production of cloths made of glass fibre, targeting curtain and non-flammable fabrics as the initial markets. Access to fibre-glass technology enabled the firm to appreciate the different markets of the technology. It was granted a license to produce windsurfing boards made of fibre-glass reinforced composites in 1973. By 1980 the firm had established itself as a leading producer of windsurfing boards.

The new access to this new market and technological knowledge was proactively used by Ten Cate to *learn* and *build up capabilities* in *composites*. In 1974, Ten Cate licensed the processing method for pre-impregnated materials made of resin-impregnated polyacril with an intention to replace the maturing fibreglass. However, due to the high production costs, the resulting products only made modest sales. The firm attempted to develop different materials with carbon fibre reinforcement which resulted in its first breakthrough composite technology to replace polyacryl in 1979. The new materials were lightweight and stronger and were cost efficient (one-twentieth of that of pre-impregnated polyacryl). The new materials also helped the firm to seize new opportunities in sports equipment, aircraft and the automotive sector. The competition in glass-fibre reinforced polymers that had long been subject to price-based competition forced the firm to gradually shift to composite fabrics made of various materials, notably carbon and aramid fibre-reinforced polymers. As the share of glass fibres in the firm's products decreased significantly the Ten Cate Glass business unit was changed to Ten Cate Advanced Composite in 1989.

This new capability in composite materials, particularly in thermoplastic composites initially obtained from licensing windsurfing boards in 1973, allowed the firm to develop the basic technology for Cetex® -thermoplastic reinforced laminates- in the 1980s, in cooperation with Delft University. Standard Cetex® products which feature polyetherimide (PEI) or polyphenylene sulphide (PPS) matrix with various reinforcements such as fibreglass, carbon or aramid allow the firm to customise solutions for a range of customers. Thermoplastic composite materials used in Cetex® was a breakthrough technology offering lower cost solutions for noise reducing materials than the established thermosetting composites for aircraft applications. It changed the technological paradigm in the market as thermoplastics can produce one panel, non-splice acoustic liner for airplanes' engine air-intakes so that the airplanes can have a very low noise profile. The traditional technology used two to three panels which caused acoustic disturbance due to the spliced joints between the panels.

The first application of Cetex® in the aircraft market was developed together with Stork Fokker and Airbus for the Airbus 340. The technology fit in with the aviation industry's requirements because of its *lightness, mouldability, rigidity* and *lower production cost.* The Boeing 787 and the Airbus A380 use thousands of components made of Cetex® technology[8]. The same composite materials can be used in different applications that include high-quality sports equipment such as the super-light frames for sports bikes and golf clubs, and medical equipment including extremely robust orthopaedic prostheses and orthoses. It shows that adoption of new materials into the existing systems fostered the development of new competencies by which it diversifies beyond its current markets and technologies.

The firm's knowledge in thermoplastic composites was further developed to provide solutions in the armour market. Although the demand for armour in the 1990s was in decline following the end of the Cold War in 1991 (see section 3.5 of Chapter 3) Ten Cate foresaw the market would increase in the future[9]. It established a new business, Ten Cate Armour, to produce body armour made of thermoplastic composites. A number of acquisitions have been made since the late 1990s, all of which were directed at leveraging its knowledge and technological portfolio and pursuing market diversification. In 1998, for instance, Ten Cate acquired 68 per cent of Ares Protection of France, a producer of antiballistic composites. Ares manufactures personnel and armoured vehicle protection and holds the

[8] There are roughly 1500 different part numbers made of Cetex PEI or PPS composite on an Airbus aircraft. This number is expected to grow significantly with the Boeing 787 and Airbus 380 as aircraft firms demand for more thermoplastic composite parts.

[9] As discussed in Chapter 3, Courtaulds closed down its activities in carbon fibres and composites including its business in the army market. Interestingly, Ten Cate just entered the market in the early 1990s. While Courtaulds disappeared after it was acquired by AkzoNobel, Ten Cate has emerged as one of the leading suppliers in composites for armour.

manufacturing rights of the Liba patent, an Israeli technology for a new generation of antiballistic materials made of *ceramic*-polyurethane materials. Furthermore, to secure its operations in the US, Ten Cate acquired 100 per cent of Bryte Technology, an advanced composite maker for aerospace and electronics industries in 1999. The acquisitions were motivated by the transfer of ownership of the patent portfolio and know-how of the acquired firms rather than the market expansion because both firms are research-led organisations whose sizes are relatively small with individual sales of €10M annually.

Ten Cate proved to be accurate in its prediction about the future market for armour. Following the terrorist attack on September 11th, 2001 there was a surge in demand in this market. The firm aggressively implemented its buy-and-build strategy to rapidly foster the development of new solutions and gain technological leadership. For instance, Ten Cate acquired a Danish firm, Roshield, which is a leading provider of tailor-made antiballistic vehicle protection and personal armour in 2007. Roshield specialises in the design and management of *armour upgrading programmes*. Ten Cate also acquired a US firm, Composix, in 2008 to broaden its technology portfolio in the advanced armour solutions made of fibre-reinforced composites and ceramics for military personnel and vehicle protection including Mine Resistant Ambush Protection (MRAP) for armoured personnel carriers, aircrafts, ships and tactical vehicles. Its capability in developing innovative products and in prototyping and designing production processes has received recognition from the US Government as one of their partners in armour development. This helps the reinforcement of Ten Cate's market position in the US.

Ten Cate established collaboration with DSM to develop vehicle armour products made of the combination of TenCate's ceramic strike face and Dyneema®. The new product has been used by the Dutch military forces in Afghanistan since October 2009.

Ten Cate has been expanding the market of its composite business outside the aircraft and military fields. Other growing markets such as aerospace, satellite communications and oil and gas are deemed to be attractive. Therefore, the firm acquired a US firm, Phoenixx TPC, a technology leader in *unidirectional thermoplastic composites* (UD) for aerospace, oil and gas exploration in 2007 and two US based firms, YLA and CCS Composite, in February 2008. These firms manufacture thermosetting advanced composite materials for various markets.

The evolution of Ten Cate's composite business clearly shows that the firm has been able to modify its composite technology portfolio to enable it to developed tailored products for different needs. The firm has moved up the value chain from manufacturing cotton textiles to developing advanced materials for high performance products. This evolution has been driven by its innovative capabilities to adopt new knowledge through different routes (primarily acquisitions) and by its entrepreneurial capabilities to read the future development. As active acquisitions and divestments must have caused organisational turbulence its success shows that it has developed capabilities to manage integration of external organisations and the disposal of its uncompetitive businesses.

Geotextiles and Geosynthetics

Coastal protection is critical and remains so for the Netherlands given that a significant proportion of the country is below sea level. A disastrous flood which hit the country in 1953 boosted the market for coastal protection. One of the firms which has been successful in developing new products for this market is Nicolon. Together with AKU, a Dutch chemical firm, the firm developed polyamide-based sand bags for bank protection in 1957. It is reported that it was the first application of synthetic polymers in the field (John, 1987). Ten Cate purchased Nicolon in response to an invitation for an acquisition from Van Heek, Nicolon's major shareholder, in 1969 (but the transfer process was not finalised until 1974) following the firm's financial difficulties that has led it to go bankrupt.

Under the management of Ten Cate, development focused on the creation of stronger, more advanced industrial textiles, particularly tough industrial textiles used to reinforce and retain dike soils. Geotextile tubes made of thermoplastic polymers - coated polyethylene and polypropylene- were developed as a replacement for polyamide due to the latter's low resistance to biological substances and chemicals[10] and its tendency to lose its strength (up to 30 per cent) on swelling in the aqueous medium (Lebedev, 1992). In 1980 Ten Cate-Nicolon expanded their business to the

[10] Materials with high level chemical resistance is necessary as geotextiles are often used for construction roads where the soils contains a pH of 5 or less

US market. In 1986, Nicolon Corporation, the US arm of Ten Cate Nicolon acquired Bradley Materials which boosted their presence in the US geosynthetic markets in civil engineering. In 1991, the firm acquired a US based firm, Mirafi, a producer of polypropylene-based materials used in roadbeds and drainage systems. The US has become the firm's largest geosynthetic market. The market in the US, however, has become saturated over the past few years. As a result, the firm has had to relocate a certain amount of production capacity to China which started its operations in 2008. Meanwhile, the existing plants in America and Europe are being modified to produce less cost-sensitive products for military markets.

To expand its geographical market, product and technology portfolio in geosynthetics, Ten Cate acquired Polyfelt, an Austrian firm, the market leader in the field in 2005. Polyfelt develops and produces natural geotextiles and geosynthetics such as tarpaulins and foils to stabilise supports for roads, railways and dams and has been a partner of Ten Cate since 1999. Polyfelt has production sites in Austria, France, Malaysia and Australia. As a result of this takeover, Ten Cate has become a leading global player in the geosynthetic market.

The evolution of competence in the field shows a resemblance to that of composite materials. Akin to the initial process of new path creation in glass fibre technology, the acquisition of Nicolon was not motivated by Ten Cate's prior knowledge and resources, but rather, by an opportunity to acquire a potential business at an affordable price. Similar to its composite business, further development of the geotextile and geosynthetic business was advanced through a combination of acquisitions and internal R&D aimed at broadening its technology portfolio and reinforcing market position. Ten Cate has been modifying its resource base through the creation or acquisition of new resources that enables it to tap into growing markets whilst reconfiguring the existing resources through divestment, the relocation of production and the modification of assets. The capability helps the firm to maintain its evolutionary fitness.

Protective Fabrics

Ten Cate Over-All Fabrics, a denim workwear division originally built in conjunction with JP Stevens, has evolved and is now known as Ten Cate Protective

Fabrics. The firm's earliest involvement in protective fabrics was through Ten Cate Glass which produced fire resistant fabrics made of fibreglass. However, as fibreglass has become very mature, the firm had to seek a *substitute* technology. The firm was intrigued by the superior performance of Nomex®, a high performance fibre produced by DuPont used in a heat and flame retardant racing suit worn by Niki Lauda (the former Formula 1 driver). The racing suit saved the driver from fatal injuries due to fire during practice in 1976. In 1978, Ten Cate Over-All Fabrics pioneered the adoption of Nomex® in Europe.

Despite the high production cost, Nomex® found niche markets for high-performance protective clothing because of its superior properties. The firm added Proban® (Rhodia), PBI (PBI Performance Products) and Kevlar® (DuPont) into their protective fabrics. By 1985, the firm was able to introduce its own PBI/Kevlar® outer shell called KOMBAT™. In the same year they developed a quilted aramid thermal barrier for the Fire Service for the first time before entering the airline seat market in the following year. The developments in this new field led to the closure of Ten Cate Over-All Fabric division in 1988 and the end of the glass fibre production in 1989. All the assets were then transferred to Ten Cate Protective Fabrics.

Following the reorganisation of the division, Ten Cate focused on developing a series of different products for heat resistant and fireproof fabric markets made of different fibres. In 1992, they introduced ADVANCE™, the first NOMEX®/Kevlar® outer shell, and in 1997, launched COMFORTBLEND™, the first Nomex®/Lenzing FR™ fabrics. In 1999, they introduced MILLENIA™, Zylon® blended outer shell. Active product development derived from the combination of different fibres and finishing techniques allowed the firm to customise the products for a range of different customers.

To strengthen their technological and market position, Ten Cate developed collaboration with Southern Mills, the leading supplier of heat resistant and fireproof fabrics in the USA in 1996. The firm was acquired by Ten Cate because of financial difficulties dating back to 2004. Currently, Ten Cate is now one of the largest suppliers of flame resistant fabrics for US military uniforms.

In contrast to the initial development of Ten Cate Advanced Composites and Geotextiles, the Protective Fabrics business was created through a deliberate search to tap into emerging opportunities in fire resistant fabrics. It was helped by its previous knowledge in fibreglass fire proof fabrics as the basis to appreciate other opportunities in the adjacent market and encouraged investment. The development of this business is greatly driven by new opportunities which emerged as a consequence of the advancement of high-performance fibres. Ten Cate licensed the technologies and built its own production facility to facilitate learning.

Contrary to the evolution of competence in composite materials and geotextiles, the protective clothing has been developed primarily through internal R&D rather than by external acquisition. It is probably due to the domination of a few large firms in the technology market, notably DuPont, which made technological competition in the field limited. In other words, other firms in the field use similar technologies. Therefore, Ten Cate developed its own products derived from a combination of technologies from different sources -or cospecialisation- as soon as the necessary resource base was in place. This allows the firm to position itself distinctly from large competitors.

As discussed earlier, cospecialisation relates to a combination of technologies to create a new or significantly enhanced product value. As Ten Cate did not conduct basic research, cospecialisation appears to be critical to create unique solutions for their customers. Such a capability proved to be vital to turnaround Southern Mills from being a bankrupt firm into a profitable business. Under the direct supervision of Ten Cate, Southern Mills combined technologies within Ten Cate's technology portfolio to develop 'Defender M', its latest innovation in flame protective military combat uniforms. The product is the result of the combination of antiballistic composite technology (Ares), fibre-reinforced composites and ceramics technology (Composix) and heat resistant and fire proof fabric technology from Southern Mills. Such a novel combination not only enables protection from heat and fire but also from bullets without the requirement for any additional layers. It is in fact a unique new solution in the market which attracted the US Army. Such a strategic deployment and utilisation of resources was masterminded by the chairman, Mr. de Vries, which illustrates the importance of top management's capabilities in creating synergies among its asset portfolio to fulfil latent demand (Helfat, *et al.*, 2007). This capability is described by Teece (2007) as fundamentally entrepreneurial and is critical to create a new playing field in a fast changing environment and improve the evolutionary fitness. (Teece, 2007)

Artificial Grass

In 1969 Thiokol Coorporation, a US-based carpet backing firm, was looking for a partner in Europe to develop and sell polypropylene-based carpet backings to replace those made of natural fibre jute. Shell, the supplier of polypropylene for Thiokol, named Ten Cate as a possible candidate. The firm's experience with the acquisition of Nicolon through which the firm successfully generated new growth encouraged it to accept the invitation for collaboration with Thiokol. This collaboration shows that reputation once again played an important role in the selection of partners. Ten Cate's lack of critical technological knowledge of the field, that is, processing technology to transform polypropylene pellets into yarns through blown extrusion, did not hinder the collaboration.

An attempt to obtain government research funding was turned down in 1970, despite the fact that it was a pioneering research project in the Netherlands with immense opportunities. The firm arranged the necessary resources independently to set up Thikolon-Ten Cate in 1971. The investment turned out to be strategically crucial as the business became the largest contributor to the firm's annual revenues in the early 1970s. The joint venture was acquired and became a wholly-owned subsidiary of Ten Cate in 1977.

Meanwhile, Thiokol Chemical in Nijverdal was seeking to develop polypropylene-based artificial grass in 1975. Artificial grass is a complementary component for carpet backing as, together, they can significantly enhance the value of each product. The performance requirements in this market were complex, including dyeability, stability of the materials, against heat and ultraviolet lights, strong bonds for the backings, an effective drainage system and function in wet and dry environments. The established technology (asphalt) could not deliver on these requirements while polypropylene showed promising properties. It required five years of development, however, before the firm finally constructed artificial grass – Thiolon®.

However, artificial grass was not Ten Cate's core business until the 2000s when it made several acquisitions to tap into the growth in demand. Ten Cate Thiolon acquired Nymplex, an extrusion firm with expertise in co-extrusion polymers, and a US based Polyloom Corp, the pioneer of polypropylene fibrillated yarn for synthetic turf and indoor-outdoor carpeting in 2000 and 2001, respectively. The acquisition helped Ten Cate to gain the necessary technologies to compete in this market, particularly in the US, as the market shifted away from polyamide-based to polypropylene-based. Polypropylene allowed a broader range of applications of synthetic turf as the technology offers better performance to fulfil the needs of more demanding customers.

The market for artificial grass has continued to grow in recent years. In 2007, the global market was €1.25 billion, growing at 20 per cent per year (www. amiplastic.com). Ten Cate's market share was around 20 per cent. The new regulation introduced by the European Football Association's (UEFA) which permitted football matches being played on artificial grass for the first time in 2005 boosted Ten Cate's grass business. In addition to R&D, Ten Cate continues to apply their buy and build strategy to accelerate the acquisition of technology and expand into different markets. In 2007 the firm acquired Mattex Leisure Industry based in Dubai. This acquisition allowed market expansion into low cost, large volume artificial grass markets such as home lawns and gardens. These markets complement their existing customised, higher value added artificial grass markets such as football pitches and golf courses which are served by the production in Europe and USA. To ensure comprehensive solutions for a variety of markets, Ten Cate broadened its patent portfolio by acquiring a Dutch firm, Edel Grass Synthetic Turf System which was its former partner in an artificial multi-turf research project in the EU Research Framework Programme 6 in 2005.

Demand in this market varies considerably as it is determined by a number of factors including the type of market (lawn, sports, parks) and weather conditions. The lawn market prefers durability rather than playing characteristics while for sports the latter is of a greater importance. Even within the sports market, different parameters of playing characteristics (ball roll, sliding friendliness and rotational friction) of each sport require different performance characteristics of synthetic grass. As the overall performance is particularly determined by the components used, Ten Cate has broadened its technology portfolio through acquisition and internal development to serve different demand characteristics. In the sports market, the firm currently provides synthetic turfs for football, tennis, hockey, golf, American football and multisport pitches.

To complement the acquisition of technology, Ten Cate teamed up with two leading synthetic turf marketing firms, GreenFields and FieldTurf Tarkett, to market the latest generation of synthetic turfs. GreenFields is a critical partner because of its extensive markets in football pitches, being appointed as the principal contractor for a number of large future projects, including the 2010 World Cup in South Africa by The Fédération Internationale de Football Association (FIFA). In addition to this market expansion, the collaboration enhances Ten Cate's present patent position in the field as the firm has also acquired the patents of GreenFields.

The carpet backing business, akin to the glass fibre and geotextile businesses, was initiated as a result of a forward looking management and its entrepreneurial capability to seize new opportunities. The firm was encouraged by its expectation of *the future opportunities* and the *rewards for being the pioneer* in the market and being an *early adopter* in Europe. This encouraged the management to take a risk and build the capability in polypropylene-based carpet backings without government backing.

The move into the synthetic turf showed the firm's intention to enhance the value of their carpet backing business by integrating a cospecialised asset (synthetic turfs) into the carpet backings. Since the firm has built the capability in the polypropylene processing technology from their activities in carpet backings and geosynthetics, selecting polypropylene as the basic materials to make synthetic turf allows the firm to align their resources, gain the advantages from increasing returns and reduce time to market. Later on, polypropylene was used in a wide range of products including plastic containers and composites, thus leveraging further the application of polypropylene. According to Teece (2007) and Helfat, *et al.* (2007), making *interrelated investments in intangible assets and utilising the same technology for different products and markets* is a critical dynamic capability. It will improve the efficiency of production systems that can have a significant effect on cost savings.

Plastics-Based Technical Components

There were two reasons that encouraged Ten Cate to enter the plastic packaging market although it was not related to its established competence in textile technology. The first was the plastic packaging boom affected by progress in logistical systems, global trade and the growth of the supermarkets in the early 1980s in which products were packaged in small plastic containers. The second was the opportunity to reinforce its plastic processing capability which up to 1977 was limited to rotation moulding to produce polyethylene windsurfing boards. Following several years of employing rotation moulding, the firm discovered that the method was suitable to produce smaller articles that were then made of aluminium such as fuel containers, sea buoys and toilet cubicles. For such products, the replacement of aluminium with plastics offered superior advantages which included durability and were maintenance-free. In 1985 Ten Cate Rotomoulding was established to serve these markets.

In 1978 Shell was seeking partners to develop a replacement for expensive lubricant cans. The performance requirements were very demanding which included being chemically inert, resistant to changing temperatures and stackable. Although the selected materials, polypropylene, was in Ten Cate's favour (they had the capabilities in the polypropylene processing technology for carpet backing and geotextiles), the production technique which involved blown extrusion, a difficult technique that needed considerable time for trial and error to determine the amount of air required for the extrusion, was beyond the firm's technical capacity. After two years of developing a capability in blown extrusion, Ten Cate approached Shell to offer collaboration in a joint venture named TtC Moulding.

In 1983 Ten Cate acquired Plasticum, a struggling injection moulding firm who manufactured aerosol packaging, caps and closures. The acquisition thus leveraged the firm technology portfolio in plastic processing technology for small items (rotation moulding, blown extrusion and injection moulding) which allowed them to diversify their range of products in a number of different market segments.

Throughout 1990s Ten Cate implemented an aggressive expansion strategy. As a result, plastics represented 80 per cent of the group's sales in 1994. However, the wave of production off shoring to the Far East and China for consumer products coupled by the economic slowdown after the September 2001 terrorist attack forced Ten Cate to scale down their operations in consumer products. The firm shifted its plastic production to more specialized areas such as specialised rollers for printers and photo-copiers (Ten Cate Enbi), and self-adhesive and heat seal base materials for labels and label materials (Multistiq). Nevertheless, since the attempt was not sufficient to keep the operation in Europe and the US, Ten Cate transferred the production facilities of Ten Cate Enbi to Mexico, Hungary and the Far East in 2000 followed by closures of operations in the Netherlands, USA, UK, Switzerland and France. Furthermore, Ten Cate dismantled their plastic business, which began with selling TC Moulding UK and NL in 1998 and 1999, respectively, and subsequently Plasticum US and France in 2001 before the final divestment of the Ten Cate Plasticum group as a whole in 2006 for €20 M. The firm divested Mega Valves group in 2005 followed by Synbra in 2006. Ten Cate Enbi is the only business remaining in the technical component business.

The plastic business demonstrates three stages of the evolutionary process throughout its course, each of which is characterised by different dynamic capabilities. The first stage was capability building characterised by distant search and learning by doing. The search to replace aluminium products showed the role of prior knowledge in plastic rotation moulding in the creation of the new business. Thus, the concept of absorptive capacity is indeed applicable in this case. The subsequent development of the capability was built through the combination of a joint venture, acquisition and internal R&D from which a portfolio of technological capability was built. The next stage was expansion, extension of production capacity and differentiation to adjacent markets by means of establishing foreign subsidiaries, the purchase of high capacity machinery and developing specialised products. The third stage was divesting uncompetitive businesses after attempts to diversify into specialised markets such as printer rollers, self-adhesive labels, drugstore products and the health sector could not prevent market maturity. Increased pressures on margins forced the firm to relocate production to Asia and closed down operations in the developed countries (cost reduction), before divesting the entire plastic packaging and other technical component businesses.

The evolutionary path provides us with an element of dynamic capabilities that has rarely been discussed in the literature on the dynamic capabilities of firms, that is, *divestment-based dynamic capabilities.* These capabilities encompass the ability to sense changing technology and market that will affect the maturity of existing businesses, reorganise the resource base (including relocation) to improve the firm's performances, separate the business from the current structures, and sell it at a reasonable, if not a profitable, price.

The divestment of the plastic packaging and technical component businesses was largely influenced by an increase pressure in competition. It appears that the firm's unique capability in combining resources to enhance value and create unique solutions (for example, composite technology and protective fabrics for Defender M, or carpet backings and synthetic turf) did not fit in with its plastic component business. It assumed that its markets (packaging for consumer products) and technologies (injection moulding, rotation moulding and blown extrusion) were not complementary to other business units, all of which were textile-based. Consequently, as the firm redefined its strategic growth areas where synergies among the technology portfolios were central to the decision, the divestment of the plastic business in 2005 seemed to be a rational solution. This ended the firm's activity in mass-produced consumer products.

Industrial Inkjet Printing

Ten Cate believes that functional/multi-functional textiles derived from the exploitation of nanotechnology in surface treatment will be one of the key technologies in the future of textile technology. Unlike the majority of textile firms that use coating or dispersions to incorporate nanomaterials onto fibres or fabrics to impart functionalities into textiles, Ten Cate uses inkjet printing. The firm began their research in the field in the late 1990s which culminated in eight patents filed in 2004-2005. The underlying technology is the method to continuously deposit droplets of functional finishing agent on fabric surfaces using continuous inkjet techniques. A patent related to the composition of finishing materials specifically developed for this purpose has also been filed. Some examples of new technical possibilities potentially emanated from this technology include fabrics that can; change colour; fabrics with solar cells; and fabrics that function as sensors. The technology is developed to facilitate the creation and improvement of new performance across business units, including advanced composites and synthetic grass. For instance, the potential synergy between inkjet printing technology and advanced composites proposed by Ten Cate for the future development of the Personal Protective Equipment (PPE) has been accepted by the consortium of the EU PPE road map development. It shows the strategic thinking of the top management orchestrating resource deployment to create and enhance values of the individual technology, or, the *managerial dynamic capabilities* (Helfat, *et al.*, 2007).

In addition to the variety of functions the technology can impart into fabrics, the method is claimed to be superior compared to the traditional methods in terms of performance quality, flexibility, efficiency and environmental benefits. This technology would enable more even and precise quantities of the materials to be deployed on fabrics, more accurate arrangements according to design specifications (patterned deposition of substances), simultaneous deployment of different functional materials in one production run, and production of small quantities without additional costs (mass-customisation). As a result, considerable timesaving could be achieved, coupled with a major reduction in waste and the elimination of water consumption. The technology is expected to offer advantages in the future which involve water and energy savings in the order of 70 per cent to 90 per cent and a reduction in the use of chemicals by approximately 60 per cent. Therefore, if such a performance could be realised, the technology would be the firm's future platform in surface functionalisation.

Following its involvement in the Digitex, a research programme under the EU Research Framework 6 in 2004, Ten Cate acquired 75 per cent of the share of British firm, Xennia Technology which was one of the partners in the programme, who owned the proprietary technologies for the development of inks/coating fluids and the related steering technology (software). The rest of the shares are owned by UK based firm Xaar, a specialist in inkjet printheads (nozzles) which is a complementary technology for the inkjet technology. The synergy between Ten Cate and Xennia is that Ten Cate can use Xenia's technology to co-develop new ink jet technology for functional textile applications, the domain that Xenia lacks. Therefore, the combined expertise of the two firms enables the generation of potentially critical knowledge and technology in the textile finishing sector.

Figure 6-6 shows the timeline of transitions in technology, product and market achieved in Ten Cate. Certainly, Ten Cate has transformed itself from a mature cotton fabric producing firm to a diversified high-technology textile firm through a lengthy process of reconfiguration of capability, technology and market. The case study shows that such a reconfiguration is a result of the creation of new capabilities and competencies in different fields involving generation, assimilation, cospecialisation and elimination of knowledge and know-how. Acquisitions appear to be the primary approach at least at the beginning of the process of de-maturity. As the necessary resource base is in place, the absorptive capacity of the firm increases to enable it to advance its capabilities within the fields or in adjacent fields through internal R&D.

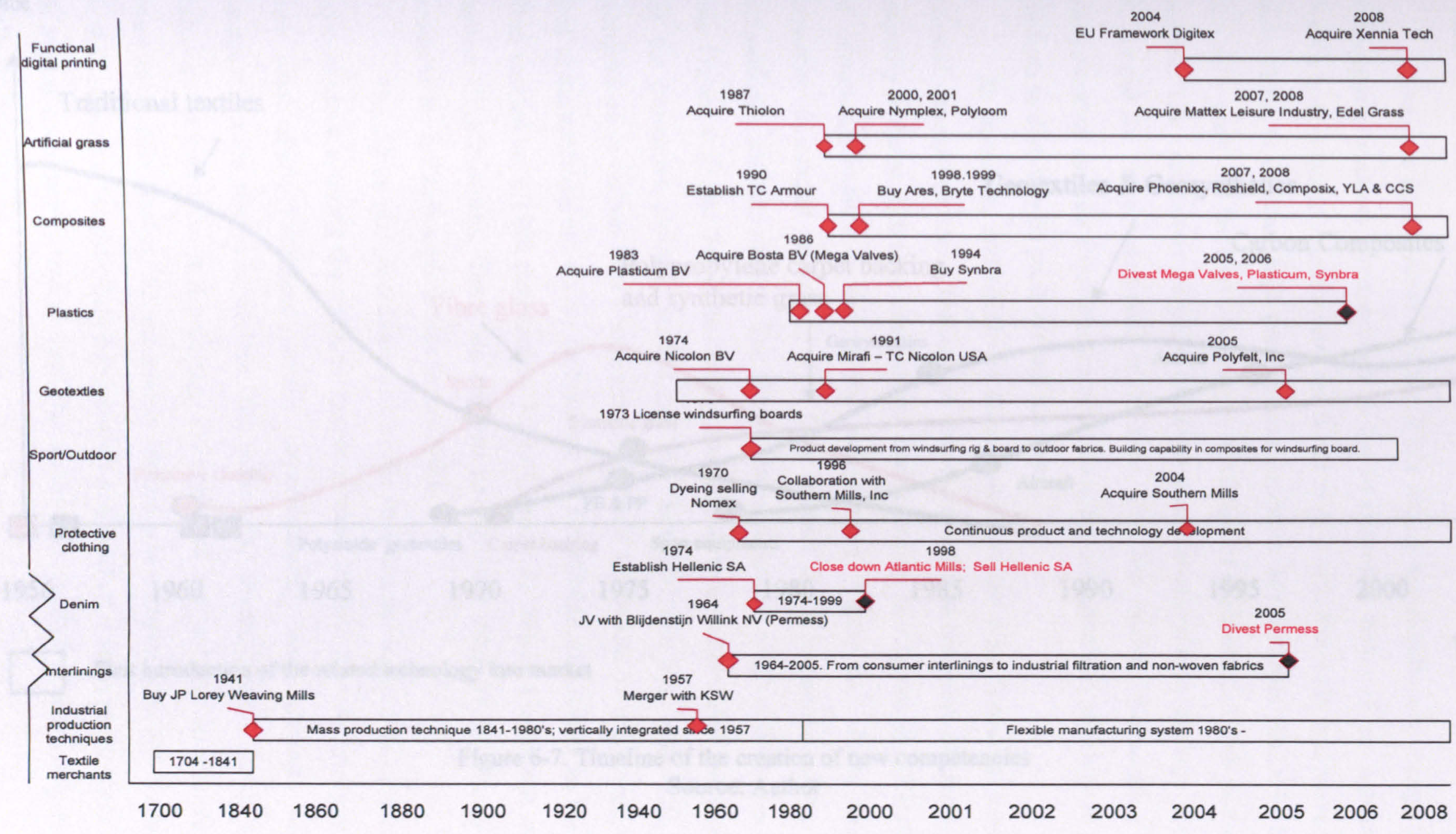

Figure 6-6. Transition timeline-major events
Source: Author

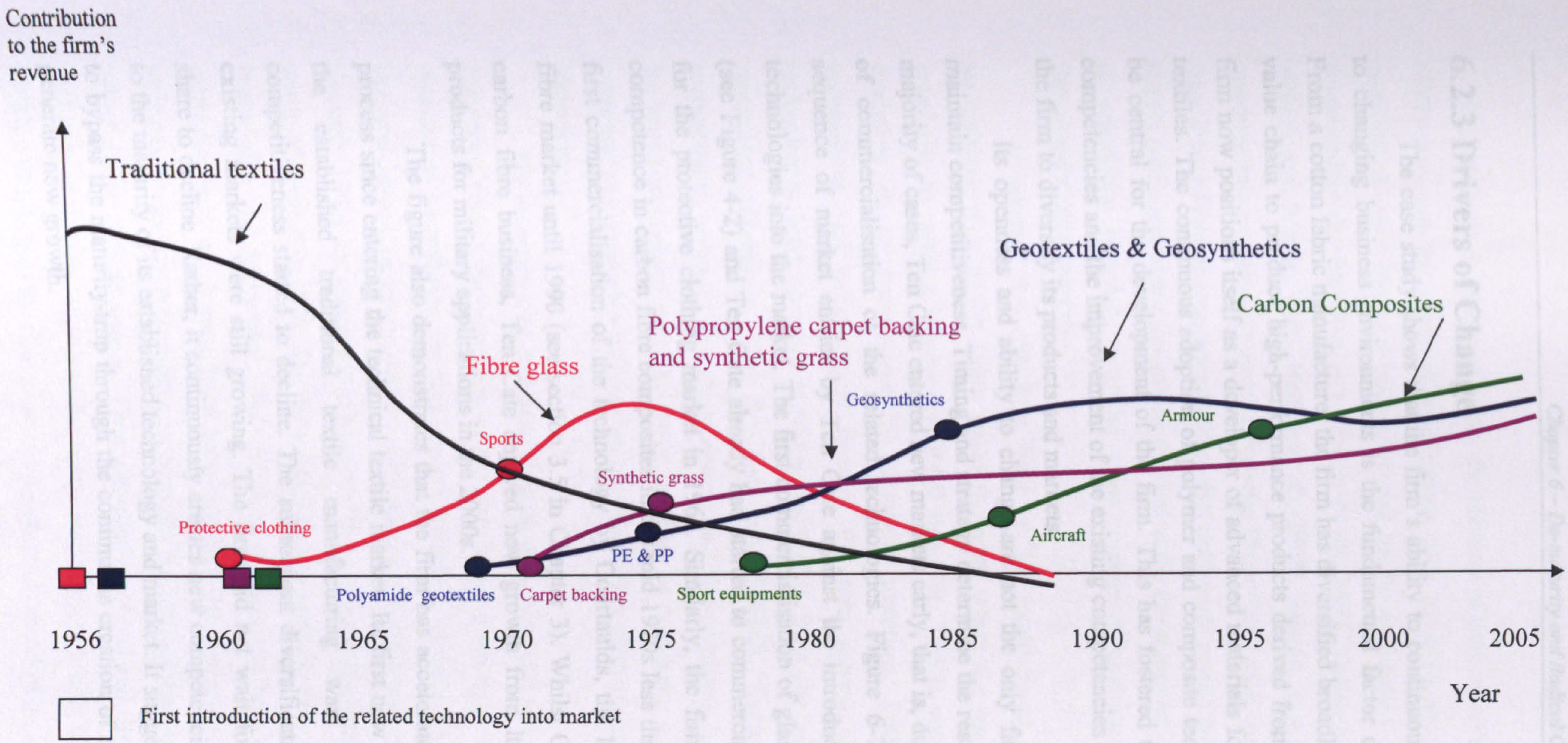

Figure 6-7. Timeline of the creation of new competencies
Source: Author

6.2.3 Drivers of Change

The case study shows that the firm's ability to continuously change to adapt to changing business environments is the fundamental factor of its sustainability. From a cotton fabric manufacturer the firm has diversified broadly and moved up the value chain to produce high-performance products derived from R&D. In fact, the firm now positions itself as a developer of advanced materials for high-performance textiles. The continuous adoption of polymer and composite technology appears to be central for the development of the firm. This has fostered the creation of new competencies and the improvement of the existing competencies which have enabled the firm to diversify its products and markets.

Its openness and ability to change are not the only factors to create and maintain competitiveness. Timing and strategy determine the result of change. In the majority of cases, Ten Cate entered new markets early, that is, during the early phase of commercialisation of the related technologies. Figure 6-7 above shows the sequence of market entries by Ten Cate against the introduction of the related technologies into the market. The first commercialisation of glass fibre was in 1956 (see Figure 4-2) and Ten Cate already had started to commercialise the technology for the protective clothing market in 1963. Similarly, the firm started to build a competence in carbon fibre composites in the mid 1970s less than 10 years after the first commercialisation of the technology by Courtaulds, the leader in the carbon fibre market until 1990 (see section 3.5 in Chapter 3). Whilst Courtaulds closed its carbon fibre business, Ten Cate enjoyed new growth from its carbon composite products for military applications in the 2000s.

The figure also demonstrates that the firm has accelerated its diversification process since entering the technical textile market. Its first new competence beyond the established traditional textile manufacturing was created when its competitiveness started to decline. The subsequent diversification started while its existing markets were still growing. The firm did not wait for its current market share to decline. Rather, it continuously creates new competencies and markets prior to the maturity of its established technology and market. It suggests the firm's ability to bypass the maturity-trap through the continuous creation of new competencies to generate new growth.

Interestingly, the method for the creation of new capabilities up to the early 1980s was not the result of a deliberate plan to seize new markets. The new capabilities were also not built up based on its established knowledge as often suggested in the literature (e.g. Teece, *et al.*, 1997, Cohen and Levinthal, 1990, Nelson and Winter, 1982, Helfat, *et al.*, 2007). Instead, it was mostly driven by opportunistic decisions to acquire growing firms. Only after the 1980s did the firm start diversification programmes through a *deliberate search* (licensing and internal R&D) combined with acquisitions that led to the development of new competencies in composite materials, artificial grass, protective clothing, geosynthetics and functional digital printing.

It appears that the firm built up its foundational knowledge through acquisitions prior to the 1980s up to the point where the necessary capacity and capability to conduct independent R&D was met. This is very apparent from the evolution of its competence in composite materials. Following a series of acquisitions and technological licenses the firm started to develop its own technologies built upon its previous knowledge from the acquired firms. From processing fibreglass, the firm adopted different thermoplastic composite technologies, ceramics and thermosetting and thermoplastic advanced composites. Its broad technology portfolio helps the firm to customise solutions for different customer requirements which in turn provide further diversification and development trajectories.

The emergence of new markets such as armour and sports has also played an important role in the evolution of the firm's competence. Complemented with its acquisition capabilities, the firm rapidly modified its technology portfolio to fulfil the new demand in this market. Its early adoption of different armour technologies in the early 1990s has enabled it to be one of the leaders in the market when there was a surge of demand in 2001. The early adoption provided the firm with the foundational knowledge and know-how. Had the firm not actively broadened its technology portfolio early on, it would not have captured the emerging opportunities whose stringent performance requirements can only be fulfilled through a combination of a set of different technologies. Thus, cumulativeness of and diversity of knowledge and know-how have improved the firm's evolutionary fitness (Cohen and Levinthal, 1990) which helped the firm to seize opportunities ahead of its competitors.

Finally, the research suggests that fundamental changes have been driven by the entrepreneurial approach of one particular figure, that is, the CEO. It was reported that since his appointment in 1998 the process of reconfiguration and diversification of the firm's competencies has been accelerated. It is perhaps related to the firm's strategy in the development of new competencies. As acquisitions often involve a major financial commitment and are highly dependent on the tacit knowledge of the top-level management, routines for acquisitions are difficult to develop. Consequently, the dependency on top management is high.

6.2.4 The Dynamic Capabilities of Ten Cate

It is evident that Ten Cate has the capability to sustain its competitiveness over a substantial period through continuous change despite facing challenges from a changing external business environment. Arguably, the firm has developed dynamic capabilities that are fundamental to its sustainable competitiveness. Its dynamic capabilities appear to be developed through its solid experience with acquisitions, divestments and R&D. As discussed earlier the firm seems to emphasise acquisitions for strategic redirection –de-maturity- and not R&D. Given the organisational complexity related to acquisitions and external integration (Ravenscraft and Scherer, 1987, Chatterjee, *et al.*, 1992) it appears that the firm has overcome the problems. Such an experience has improved its flexibility and adaptive character to varying circumstances.

There are four critical capabilities that have been identified that contribute to the effective implementation of de-maturity through acquisitions. First, is the *entrepreneurial management* that encourages risk taking to enter new, unrelated markets and to invest in new technologies that are away from its established knowledge. Such a path breaking change liberates firms from bounded rationality (Karim and Mitchell, 2000) or organisational rigidities (Vermeulen and Barkema, 2001). It confirms Teece's (2007) and Helfat, *et al.* (2007) arguments that firms are shaped but not necessarily 'trapped' by its past and that new investment can change the course of direction. This finding suggests that the path-dependent aspect of absorptive capacity which argues that firms need prior related knowledge in order to recognise new opportunity (Cohen and Levinthal, 1990) seems to be weakly supported, at least in this case. Without prior knowledge in fibreglass, geotextiles or synthetic turf, Ten Cate was able to build capabilities in the field through a minority ownership or acquisitions which allowed access to knowledge in the relevant technology and market, and encouraged learning. It appears that the entrepreneurial capabilities of the management, adequate financial resources and networks of business partners that enabled access to new resources and learning can compensate for the lack of prior knowledge.

The second is the firm's capability in the *selection of partners* for acquisitions[11]. For Ten Cate, one critical objective when it wants to select a partner is to broaden the firm's technology portfolio and market position. Therefore, *synergies* between the existing and targeted technologies and markets are critical factors that determine acquisitions. Prior to an acquisition, Ten Cate initiates collaboration, alliances or intensive contacts to *explore* the potential synergies between the two different firms. The acquisitions of Thiokol, Southern Mills, Mirafi and Xennia are examples. Furthermore, acquisitions should consider other strategic complementary knowledge in the context of technology as a system. As an illustration, one of the reasons Ten Cate acquired 75 per cent (rather than 100 per cent) of Xaar's ownership in Xennia is to keep the association with Xaar who owns a critical complementary technology and yet allow the firm to dictate the future development of the technology. This view, therefore, enhances the concept of the acquisition-based dynamic capabilities (Helfat, *et al.* 2007).

The next factor is capability to implement synergies to enhance the value for customers or to create new markets. One illustration of this is the acquisition of Phoenixx and YLA which was motivated by the firm's desire to complement its thermoplastic composites with thermosetting composites for aerospace and oil and gas sectors. By appropriating a set of different technologies, the firm can customise solutions for broader customers within the market segments. In another instance, the acquisition of Ares and Composix broadens the firm's market base in the armour market as it allows the firm to enter both personnel (Ares) and vehicle (Composix) armour. In addition, the unidirectional thermoplastic composite of Phoenixx enables the creation of new products for Cetex® product lines as it permits the production of

[11] The interview indicates that a number of factors including price, hidden value, geographical position, technology, people and competitors are taken into consideration in the partner selection.

lightweight thermoplastic composite fuselage[12]. This new technology reinforces the market for Cetex® products in the aviation industry. Teece (2007) refers to this as *cospecialised assets,* that is, joint uses of different technologies to significantly enhance the value of products or create unique products. As the technology portfolio is historically dependent, cospecialisation can generate idiosyncratic assets from which unique products can be developed. The ability to select external technologies and combine them with internal technologies within a firm's portfolio by which the end product's value is significantly enhanced is an important dynamic capability. This kind of synergy also permits the efficient and effective use of resources which would have an impact on cost savings.

It is important to note that synergies are not only a crucial factor in acquisitions but also in divestment. The divestment of the plastic packaging business is an example. Divestment-based capabilities are as equally important as acquisition-based capabilities in that it shows the leader's capabilities to achieve evolutionary fitness by disposing of uncompetitive businesses. This helps to reduce the firm's liabilities and transfer the resources to other growing areas. This capability needs firms to overcome barriers commonly impede sales of business assets that include sunk costs, resistance from the labour union and even sentimental reasons due to historical legacy (see Chapter 7 about the traditional leather business of Freudenberg).

The fourth factor is the capability to manage organisational turbulence as a consequence of acquisitions. The literature contends that the difference in culture, management style and knowledge-base can have detrimental effects on acquisitions (Ravenscraft and Scherer, 1987, Chatterjee, Lubatkin, Schweiger and Weber, 1992). The firm's first shift to a decentralised structure in 1990 appears to have contributed significantly to its ability to manage the adverse effects of integration. The decentralised organisation is designed to have a rather horizontal structure (flat) comprises of *networks of organisations* -globally interconnected organisations and people- such that it is flexible and easily reorganised (changing, adding or removing firms or partners). Such an organisational form is strongly characterised by coordination rather than hierarchical control and places greater emphasis on

[12] The body of an airplane, containing the cockpit, passenger seating, and cargo hold but excluding the wings

knowledge rather than scale and scope, and on human resources and self-organising than corporate planning and bureaucracy (Whittington and Mayer, 1997, as in Pettigrew and Fenton, 2000). Therefore, the acquired firms can maintain the necessary culture and management style which are deemed to be beneficial for their growth and yet have to develop routines for coordination.

The implementation of the networked organisation however entails inherent challenges which may hinder performance improvements (Ruigrok, *et al.*, 2000). The complexity of managing coordination of a large number of constituencies in a network is rather significant. Firms have to balance between coordination and autonomy, build up synergies among organisations or divisions (strategic coherence), and share innovative culture across organisations. Furthermore, the management of a networked organisation requires a new understanding on the role of cross-divisional management in which the management in one business has a role to provide opportunities for other organisations or divisions in the network. In Ten Cate, the role of top management is critical to encourage synergies and promote the corporate culture across the firm. For instance, the management has been able to create new synergies among different firms specialising in different technologies, located in different countries to develop new products and improve the performance of the firms involved (see for example the development of Defender M).

Other critical capabilities required to successful acquisitions of knowledge or technology are those related to the *availability of resources, the degree of complementarities* and *timing*. The first two factors determine the means of acquisition (internal R&D, licensing, joint venture, alliances or firm acquisition), although one pathway (alliances) could lead to others (joint venture or acquisition). Timing, on the other hand, relates to the managerial dynamic capabilities in predicting the time needed for the development process, for the potential users to accept the new products and for the competitors to catch up the firm's progress. According to Cohen and Levinthal (1990), timing is critical particularly for the technologies operating in fast moving fields because it could lead to two contradictory implications. Investing early on in an unproven technology, whilst offering the advantage as the first mover, entails the risk of financial loss if the technology never takes off and of missing the opportunities to gain advantages from other (competing) technologies. On the other hand, investing at a later stage of technological development, whilst less risky, may deny the opportunity associated with the early exploitation of the technology. The competitors' advances in mastering the technology and their domination of the market can obstruct the opportunity for the late comers. Courtaulds' unsuccessful attempt in the commercialisation of synthetic fibres as discussed in Chapter 3 is a useful example.

To manage the risk associated with the adoption of technologies Ten Cate now tends to invest in a number of emerging technologies and engage in a number of different strategic networks. This gives the firm access to different technologies that belong to other organisation without the obligation to invest heavily in each of them. In other words, the approach permits access to knowledge on a preferred basis. This is an attractive alternative particularly when costs and the complexity to manage diverse knowledge hinder innovation. Such a research strategy permits lower levels of risk, cost and complexity but it also requires shared profits and ownership. Consequently, R&D and business strategies need to be adapted to meet the challenge of the new paradigm.

This new approach exhibits the open innovation paradigm (Chesbrough, 2006). In today's competitive environment firms have to collaborate and build alliances with, or license from other firms in order to have accesses to technologies generated from outside the firm. Helfat *et al.* (2007) suggested that network of alliances is a simpler and less-expensive method for acquiring external knowledge than acquisition. However the method is only applicable when the extent of the necessary contacts (similarities or synergies) allows them to work efficiently and effectively. In the case of greater points of contact are required, acquisition usually is more favourable.

This new approach may create a new stream of dynamic capabilities that has never been discussed in the literature. The dynamic capabilities to manage successful alliances have to include the capability to manage interaction, transaction and transfer of knowledge from the network to the individual members. Governance associated with contractual, ownership and monitoring issues as well as trust and reputation are also critical.

This section shows that dynamic capabilities evolve as a consequence of attempts to improve the firm's evolutionary fitness in a changing business environment. The capability links the firm's technological capabilities with organisational capabilities. Organisational capabilities can be viewed as a measure to improve the impact of the firm's technological capabilities to its performance. Therefore, it is argued that the capability to *adapt* the *organisational capabilities* in accordance to the development of the firm and the future path it is pursuing is a unique and important dynamic capability as it will eventually enhance the evolutionary fitness of the firm

6.2.5 Implications of De-maturity at the Firm Level

It is evident that Ten Cate has by passed the maturity-trap and initiated the process of de-maturity. The firm has built up its dynamic capabilities through its solid experience with acquisitions, divestments and R&D. The firm started to diversify its knowledge-base and know-how in the 1960s during which its traditional business, traditional textile manufacturing, began to lose its competitive advantage. Interestingly, the foundation for the process of de-maturity was built through its tradition in acquisitions and learning from the acquired firms rather than R&D as suggested by Abernathy *et al.* (1983). It excels in screening the potential partners, price negotiation, firm integration, synergy building and divestment. The implementation of this capability has an impact on the radical change and increased diversity of the firm's resource-base. This is a behaviour which differentiates the firm from the majority of struggling firms in mature industries where more radical responses are often eschewed despite attempts to defend their mature businesses have failed (Abernathy, 1978, Sull, 2000). Meanwhile, its R&D capabilities were built later as the firm learned from the acquired firms which had R&D capacities.

Acquisitions have enabled the firm to break its technical and cognitive constraints. Acquisitions help the firm to appropriate complementary knowledge and other resources that are distant from the current ones. This helps the firm to create new knowledge and capabilities away from its traditional businesses, providing the firm with alternative pathways to initiate de-maturity. Diversity increases the probability to initiate de-maturity. In fact, diversity improves the firm's ability to adapt to changing external conditions as it allows the firm to develop new combinations of technologies to generate new knowledge. However, acquisitions need to be managed so that the acquired knowledge can be assimilated and integrated to the existing systems from which a new combination of knowledge –or cospecialisation- to provide unique solutions for customers can be generated.

Furthermore, there are a number of factors which have been identified to be highly relevant to the process of de-maturity through acquisitions. First, is the importance of *business networks* to appreciate opportunities in distant fields. The prior related knowledge suggested by Cohen and Levinthal (1990) as the prerequisites to appreciate new opportunities could be in the form of the knowledge of the partner firms as illustrated in the case of JP Stevens for glass fibres and Thiokol and Shell in carpet backings. In other words, prior knowledge does not have to be generated internally.

The *reputation* of Ten Cate as the largest and most successful textile firm in the Netherlands appears to play a significant role in attracting new partners for new projects. The partner firms persisted with collaboration with Ten Cate although the latter did not possess the necessary capabilities in the new fields. Reputation should be complemented with *entrepreneurial management* who have the capability to sense and appreciate distant opportunities and are willing to take the risks to orchestrate and deploy the necessary resources to seize them. *Learning by doing* is a critical process to build capabilities in new fields through acquisitions. Learning can be undertaken through a combination of *alliances, collaboration and internal R&D*.

It is important to note that de-maturity is not a one-off process. Rather, firms have to constantly reinvent themselves through the continuous creation of new markets, products, knowledge and technologies. This allows firms to adapt to changing competitive environment or, moreover, to shape the environment (evolutionary fit) and avoid the maturity-trap. The evolution of advanced composites, protective clothing and artificial grass shows the manner in which Ten Cate has continuously reinvented its businesses to remain competitive in a changing environment. To sustain such a strategic change for a considerable period, firms need a set of dynamic capabilities beyond the knowledge generation capability. Organisational processes and structures that permit the management of change and quick decision making; routines that allow communication and share of knowledge; and a flexible approach to long-term investment (as opposed to short-termism to gain quick profits) are amongst organisational capabilities required to manage and reinforce changes.

6.3 Conclusion

The case study shows that the capability to continuously change to adapt changing business environments is the foundation of long-term competitiveness. It illustrates that the firm has a certain level of innovative capabilities to enable it continuously change and adapt to different business environments. Ten Cate has developed its innovative capabilities through solid experience in acquisitions and divestments. The development of innovative capabilities of this nature suggests that acquisitions are not only for market expansion and diversification, but, more importantly, for learning new knowledge and the development of new capabilities. Acquisitions have been the primary means to initiate de-maturity. The firm has experienced a series of organisational turbulence as this approach often requires radical change in the firm's organisational structure and routines. The firm's experience of managing the turbulence has enabled it to break organisational inertia, resulting in a highly adaptive firm.

This capability has been complemented with capabilities in R&D which have been built up as the firm entered markets where competition was determined by product performance than lower costs. R&D is often performed to generate new combination of knowledge belongs to the acquired and existing firms. In so doing the firm has been able to continuously generate idiosyncratic capabilities. The diversity of its competence helps the firm to adapt to changing business environments.

To develop such capabilities, the management has to have the courage to expand into technology and market domains that are not related to the firm's established knowledge. The case study shows that such a shift requires a set of dynamic capabilities which include technological and organisational capabilities. Whilst technological capabilities are required to ensure fitness between the product performance and demand, organisational capabilities are to ensure the optimum benefits from the technological capabilities. Similar to technological capabilities that are improved and diversified over time organisational capabilities also experience changes in accordance to the development of the firm's competencies and strategies. Those capabilities have to be built up over a long period and embedded into the firm's culture.

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7

Freudenberg: De-maturity and Incremental Change

7.1. Introduction

As discussed in Chapter 4, the German textile industry is the largest technical textile producer in Europe and generates the second highest added value behind the European leader, Italy (Eurostat, 2007). Its productivity, however, has been significantly higher level than Italy by an annual average of 30 per cent between 2002-2004 (Eurostat, 2005, 2006, 2007). This suggests that the industry has significantly reduced its labour requirements by advanced equipment to produce higher value added products. Indeed, 40 percent of its production is for technical textiles, the market segment that has a much higher added value than other segments (clothing textiles and household textiles). The industry has transformed itself from a low value-added industry into an increasingly high technology industry.

One of the critical factors which facilitated such a transformation was the diffusion of synthetic materials into the textile industry which commenced in the last two decades of the 19th century. As discussed in Chapter 4, synthetic materials have played a central role in the competitive advantage of the European textile industry since the turn of the 20th century. Germany was one of the earliest countries to experience the widespread diffusion of synthetic materials into the textile industry with the adoption of synthetic dyes. Although the dye was invented in Britain its diffusion in the country was limited to a few firms due to its strong patent laws which encouraged monopolistic markets. In Germany, on the other hand, a lack of patent laws allowed any firm to adopt the new technology, hence, intense competition. This did not only facilitate diffusion but also forced inefficient firms out of the market. The adoption of synthetic materials into textile products was reinforced by the government's strategic research agenda to reduce dependency on imported natural materials, particularly during the years leading up to the Second World War. The government forced textile firms to progressively integrate synthetic materials into their products and to invest in synthetic materials production. As a result of the policy, most German textiles had some synthetic content by 1939 (Hoschle, 2004). On the contrary, British textile firms concentrated on regaining their market share in the cheap cotton product market through cost reduction (see Chapter 3).

The early diffusion of synthetic materials into the textile industry permitted the German textile industry to accumulate larger stock of relevant knowledge than its competitors. As the rate and direction of technical change is determined by the stock of knowledge and investment at any given point in time, those with a greater stock of technological knowledge has a greater advantage (Rosenberg, 1994). This appears to be the underpinning factor of the transformation of the German textile industry and, moreover, of its sustainable competitive advantage. However, this advantage has to be complemented with an openness and ability to change, an entrepreneurial attitude, a long-term vision and a flexible approach.

Despite its competitive advantage, it does not necessarily mean that the industry not been hit by competition from low-cost countries. During the transition process, as with the other EU countries, the German textile industry experienced a severe decline after the end of World War II with the emergence of low-cost competitors. The loss of employment reached over 260 000 between 1970-1986, the second highest figure after Britain (Nelson, 1987). In such an unfavourable situation, Germany attempted to arrest the decline through the improvement of productivity by means of rationalisation and outward processing to low-cost countries which started in the 1960s (Dolan, 1983). Despite the loss of employment Germany maintained its competitiveness in its respective markets and competed favourably with the low-cost countries. In other words, Germany's strategy compensated for the loss of employment with the less rapid decline in its competitiveness (Shepherd, 1981).

Germany's strategy to compete with low-cost countries was once again very different to that of Britain. The latter chose mergers and acquisitions to reduce capacity, consolidate the market and integrate the whole production stages. As discussed earlier Britain suffered from long-term decline because the strategy failed to restore its competitiveness in the mature market. In brief, whilst the loss of employment in Germany could be attributed to improved labour productivity, Britain's rapid industrial contraction was predominantly caused by a severe loss of competitiveness.

This suggests that Germany's performance was the result of the industry's innovativeness rather than government protection. In contrast to Britain and Italy, Germany resisted protectionist measures as the government had less interest in the protection of an industry that contributed little to the country's economy (Dolan, 1983). In fact, the country's agreement to join the Multi Fibre Agreement (MFA) was not to seek for protection but, rather, to comply with the obligation as a member of the then European Community following the community's ratification of the agreement. Its industrial policy, however, encouraged competition rather than protection of uncompetitive firms (Toyne, *et al.*, 1984). Textile firms were forced to improve their productivity through rationalisation and relocation of production to defend their businesses.

Germany's R&D and industrial policies encouraged a radical shift of the knowledge-base at the industry level which involved changes in technology and production, distribution systems, organisational structure and value chain. The shift helped the industry to create new competencies and capabilities in the development and commercialisation of technical textiles whose performance criteria were very different from their traditional markets. The diversification into higher value added textile markets permitted the industry to escape from the harsh cost-based competition in the traditional textile market. This provided the industry with an alternative route for growth when their traditional market collapsed in the 1960s-1980s.

The experience of the German textile industry shows that a mature industry can be rejuvenated to become a knowledge-based industry. The rejuvenation involves the shift in the basis of competition from cost advantage to technical performance. This is in fact the fundamental concept of de-maturity. Firms within the industry have experienced a strategic redirection characterised by a radical shift in competencies and core businesses. As is discussed later, such a transformation was achieved through the creation of a series of new competencies and capabilities over an extended period of time. This was helped by a radical change in the firm's knowledge-base complemented with reconfiguration of its strategic resource-base[1] through new investment.

The following cast study vividly illustrates a transformation at the firm level. Freudenberg started its diversification strategy from leather tannery into higher valued added products in seals in 1934 and this was followed by the development of nonwovens in 1936. Up to now the firm has successfully maintained its leadership in seals and nonwovens for diverse applications although the current technology is very different from the traditional one. In nonwovens, the firm has adopted various synthetic fibres (including polyamide, polyester and polypropylene), processing technology (such as dry-laid, spun-bonded, wet-laid, spun-laced and electrospinning) and finishing technology (including a range of coating and plasma technologies for surface modification). Its wide range of technology and capability portfolio allows the firm to combine different materials and technologies to develop a vast range of products for various applications, ranging from apparel and garment to the energy and medical sectors. This shows the firm's ability to continuously develop new products derived from new technology to catch up with the pace of changes in the market and technology.

The creation of new competencies and capabilities has provided Freudenberg with alternative paths of growth which have helped the firm to adapt to changes in technology and market trends (evolutionary fitness). This has also fostered the firm to overcome organisational inertia, a common affliction of large mature firms (Sull, 2000). The main argument of this chapter is that a strategic change of this nature requires a radical transformation in the strategic[2] and organisational aspects of the firm (Doz and Prahalad, 1988). As argued in Chapter 6 whilst technological innovation is vital to the creation of new competencies, organisational capability is required to direct and manage the process of change and to assure that the process can continuously provide firms with new pathways to improve and create new

[1] Resource-base includes knowledge-base, skills, processes and machineries (Helfat, *et al.*, 2007).
[2] The strategic aspects of the firm include resources (the diversity of knowledge and know-how, capabilities and human resources), capital (including equipment and other facilities) and networks.

competitive advantages. Indeed, Freudenberg believes that its ability to *initiate* and manage *continuous* change is the foundation of its long-term success.

The case study discusses the transformation of Freudenberg Nonwovens which originated as a leather tannery to become the world's oldest and largest nonwoven producer. In particular, it analyses the *factors* that drive and foster organisational transformation, the *mechanism* to build up new competencies and the *capability* of the firm to continuously initiate and manage the process of change. In the following section, the current state of Freudenberg and the need to initiate radical change is proposed. Later on, the firm's strategy to undertake such changes and its pathways to generate new knowledge and reconfigure its resource-base are discussed. In section four, the detailed process of resource configuration and the creation of new competencies by which it radically changes the direction of the firm and avoid the maturity-trap will be examined. The implications of this on the evolution of competencies and the dynamic capabilities of the firm which has had an impact on the firm's de-maturity and sustainable competitiveness are elaborated on.

7.2 Freudenberg & Co

Freudenberg is a family-owned business and belongs to 300 members of the family of the founding father, Carl Johann Freudenberg. In 1849 he started his business empire by establishing a leather tannery business in Weinheim. In 1934 Freudenberg started the diversification process followed by a comprehensive transformation processes. The firm is now one of the oldest and largest producers of nonwoven fabrics for a variety of applications, in addition to being a major global producer of seals, vibration control technology components, and chemical specialties (lubricants). The Freudenberg Group operates under a decentralised structure comprises of a parent firm and four business areas, within which 14 business groups and two divisions are managed Figure 7-1. The business groups oversee 434 firms which run their businesses autonomously. The parent firm controls, coordinates and monitors the activities of the firms and provides advice and support to the business groups. The group had a turnover in excess of €5 billion and employed 33 000 people in 2008. The nonwoven business contributed to over 15 per cent of the turnover during the same period.

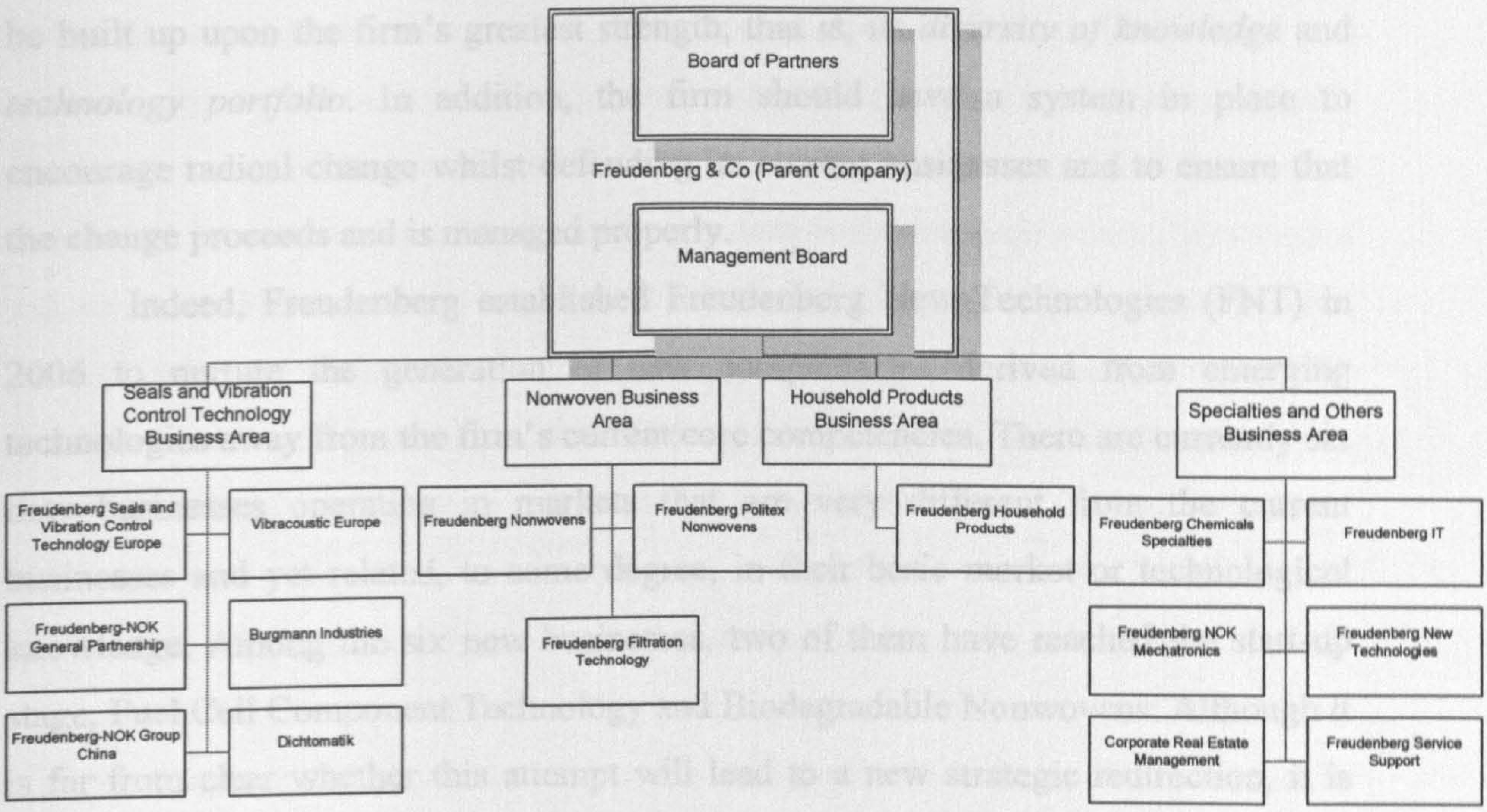

Figure 7-1. Organisational structure of Freudenberg
Source: Adaptation from the website of Freudenberg & Co

The production of seals and nonwovens has emerged as the firm's new core businesses since 1960 and replaced its traditional competence in leather processing. It took the firm 30 years to establish the new competencies and gain global market leadership. In recent years, however, the consumer nonwoven market has reached maturity and been effected by cost pressures. The contribution of nonwoven business to the firm's turnover has fallen from 40 per cent in 1980 to 15 per cent in 2008. It appears that Freudenberg needs to revive the nonwoven business. There is an urgent need to develop new competencies away from its current mature markets, capitalising on emerging technologies and markets just as it did 75 years ago when the nonwoven business was initially established. In other words, Freudenberg needs to repeat its historical feat if it is going to manage a successful strategic redirection.

Indeed, the firm's experience demonstrates that the *modification of knowledge and resource-base* from which new competitive solutions for emerging markets can be developed is the only way to thrive. However, the complexity to master a range of technologies and the intensity of the competitive environment today is very different from that in the 1930s. Thus, a more prudent consideration concerning the new direction to pursue and avenues to achieve is critical. To increase the likelihood of success in any new direction, the new capabilities should be built up upon the firm's greatest strength, that is, its *diversity of knowledge* and *technology portfolio*. In addition, the firm should have a system in place to encourage radical change whilst defending its current businesses and to ensure that the change proceeds and is managed properly.

Indeed, Freudenberg established Freudenberg New Technologies (FNT) in 2006 to nurture the generation of new competencies derived from emerging technologies away from the firm's current core competencies. There are currently six new businesses operating in markets that are very different from the current businesses and yet related, to some degree, in their basic market or technological knowledge. Among the six new businesses, two of them have reached the start-up stage, Fuel Cell Component Technology and Biodegradable Nonwovens. Although it is far from clear whether this attempt will lead to a new strategic redirection, it is apparent that the firm is preparing itself for a strategic change in the future. It shows its ability to take action well in advance to safeguard its future against uncertain threats and to equip itself with the necessary resources to harness emerging opportunities. Without a doubt, Freudenberg is a highly entrepreneurial and dynamic organisation.

7.2.1 Innovation and the Development of Knowledge and Competencies

Innovation has been the foundation of the firm since its early days. Its prowess was demonstrated by the fact that the firm was the first tannery for polished leather in Germany and the pioneer of the adoption of the chrome tanning process in Europe. Chrome tanning replaced the long-standing industry standard, vegetable tanning, in the late 19th century. The firm was also central in orchestrating a fundamental change in the leather trading systems in Europe from a weight-basis to a surface-basis. In the 1930s the firm was the first firm to produce leather seals in Germany and nonwoven fabrics in Europe. The tradition continues up to the present day as the firm continuously creates new competencies to address demand in emerging markets. Certainly, the firm has built up an 'innovative culture' aimed at leadership in the relevant technologies and markets since the 19th century.

Freudenberg has learned from its 161 year history that long term success can only be achieved through managing innovative activities in such a manner so that a continual stream of innovative products can be produced. Technological innovation on its own is insufficient to attain and retain long-term competitiveness. Innovation has to be *embedded in the corporate culture* and *supported by entrepreneurial management.* As Hamel & Prahalad (1991) argue top management needs to be firmly committed to innovation and demonstrate entrepreneurial leadership. They have to devise the appropriate organisational structure and use strategic resources efficiently to promote and sustain the competitiveness of the firm. Therefore, the necessary infrastructure (including networks), resources, and organisational processes and capabilities have to be in place to encourage innovation and support its implementation. In other words, the benefit of technological innovation to the firm's competitive advantage can only be harvested if it is complemented with organisational innovation.

The rest of this section analyses innovation as the means to generate new knowledge and competencies in Freudenberg. Subsequently, the manner in which the firm encourages and manages a continuous process of innovation from idea generation to commercialization is discussed. It is argued that the generation and adoption of new knowledge can help the firm to increase the diversity of knowledge and technology portfolio. This can generate new competencies to create new paths away from its original roots and bypass the maturity-trap. A diverse knowledge and technology portfolio can improve the firm's resilience in a changing business environment. In other words, *diversity* improves the *evolutionary fitness* of the firm, the foundation of a sustainable competitive advantage (Helfat, *et al.*, 2007).

Research and Development

Research and development (R&D) has played a central role to the firm's transformation. Its central function is to generate new knowledge and know-how that can potentially create competitive advantage in the short, medium and long term. R&D translates new knowledge and know-how into competitive products through the new product development process. Its commitment to R&D is demonstrated by a consistent increase in R&D expenditure (Figure 7-2). The average percentage of

R&D expenditure in relation to turnover (R&D intensity) was 3.5 per cent, surpassing the industry's average ratio both at national and European levels between 2000-2003 (Marin, *et al.*, 2008).

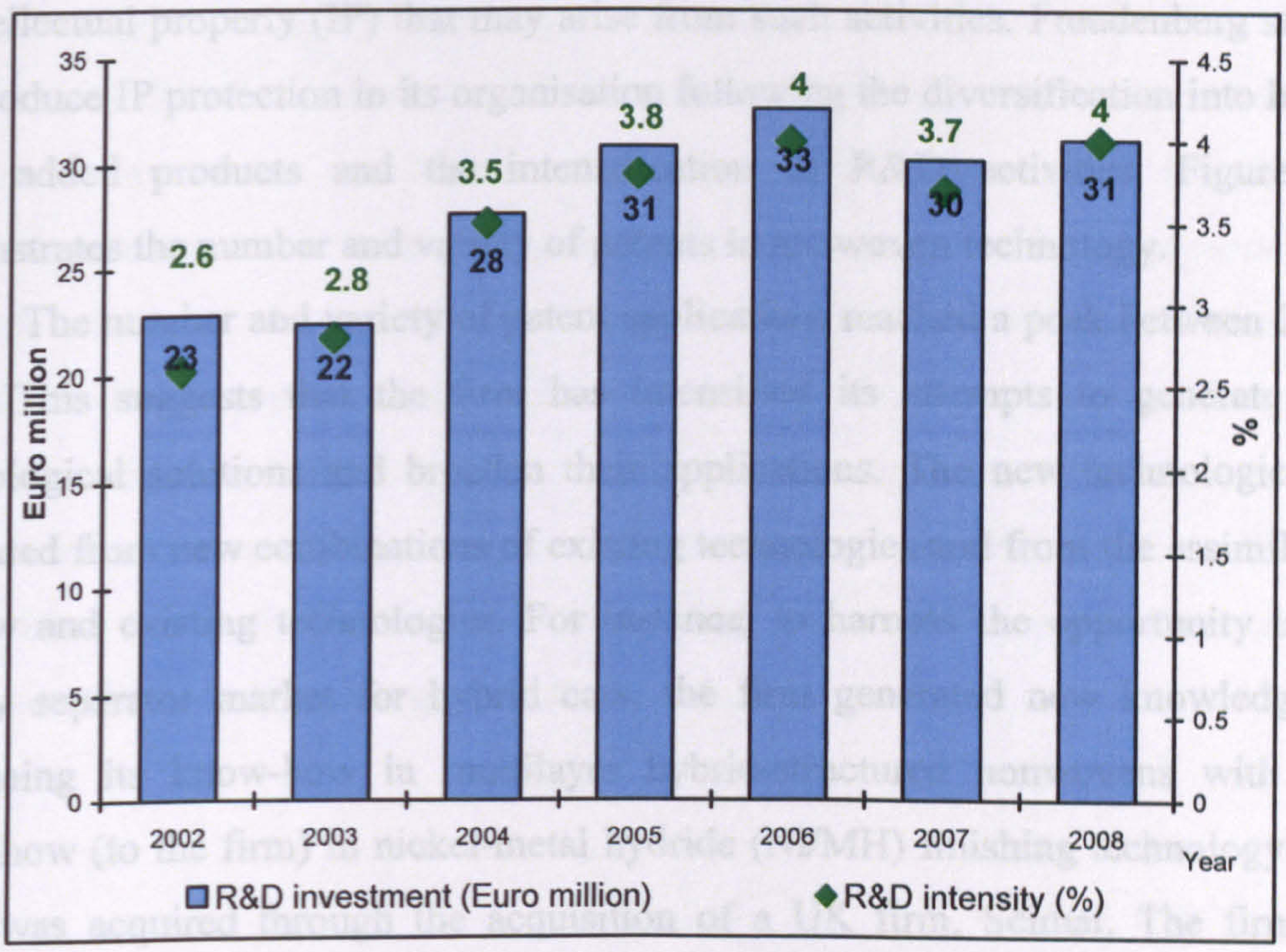

Figure 7-2. Research and development expenditure of Freudenberg Nonwovens, 2002-2008
Source: Freudenberg Annual Report, 2002-2008

Formal R&D programmes started in 1934 to support the first diversification attempt in the development of leather seals. The firm realised that its entry to the automotive seal market has *shifted its competitive environment*. While in the patent leather market the firm competed to improve the product's aesthetic appearance before technical performance, the new market demanded the opposite. Therefore, Freudenberg established the Main Laboratory and Central Workshop to lead R&D in new products and processing technology, respectively[3]. This new organisational function allowed the firm to monitor the development of technology and competition in the new market. The information could be used by the management to take the necessary action to *anticipate* (rather than respond to) changes in market and technology. This R&D function has become one of the main sources for the creation of the firm's new competitive advantage. This strategy is very different to the strategy of Courtaulds as discussed in Chapter 3 when it did not change its strategy

[3] The Main Laboratory has developed to become Freudenberg Research Service while the Central Workshop is now Freudenberg Systems and Tool Engineering.

to adapt to the new competitive environment following its entry to the rayon fibre market.

An increase in R&D activities has to be complemented with better protection of intellectual property (IP) that may arise from such activities. Freudenberg started to introduce IP protection in its organisation following the diversification into higher value added products and the intensification of R&D activities. Figure 7-3 demonstrates the number and variety of patents in nonwoven technology.

The number and variety of patent applications reached a peak between 2000-2004. This suggests that the firm has intensified its attempts to generate new technological solutions and broaden their applications. The new technologies are generated from new combinations of existing technologies and from the assimilation of new and existing technologies. For instance, to harness the opportunity in the battery separator market for hybrid cars, the firm generated new knowledge by combining its know-how in multilayer hybrid-structured nonwovens with new know-how (to the firm) in nickel-metal hydride (Ni/MH) finishing technology. The latter was acquired through the acquisition of a UK firm, Scimat. The firm has recently integrated emerging technologies such as nanotechnology, electronic textiles and biodegradable polymers into its research programmes in order to build new capabilities in existing and growing markets. It includes cleanroom filtration made of hybrid synthetic nanofibres and the Atmospheric Pressure Plasma Liquid Deposition Technology (APPLDT) - for the deposition of very thin layers of functional materials on nonwoven fabrics and polymer films. A recent trend in exploiting biodegradable polymers is also being investigated for the development of electro-spun webs made of lactic acid.

Since the early development of nonwovens in the early 1930s the firm has filed a number of patents. As the initial market for nonwoven was to substitute leather products, the reappearance of leather post World War II appeared to halt the development of nonwovens. No patent applications were published between the mid 1940s to mid 1960s. The number of patents and the diversity increased with the development of technical nonwovens in the 1970s. There was another significant increase after 2000.

Increased patent diversity indicates an increase in the variety of knowledge accumulated by the firm. Diverse knowledge and technology provides an opportunity to develop synergies –or cospecialisation - among the firm's idiosyncratic assets to develop unique products and technologies (Teece, 2007 , Helfat, *et al.*, 2007). As discussed in the previous chapter, diversity will improve the firm's absorptive capacities and improve its ability to recognise new opportunities beyond its traditional boundaries (Cohen and Levinthal, 1990). This in turn can encourage investment to harness the opportunities. Investment in different knowledge domains will have an impact on the *modification* and *reconfiguration* of the resource-base which a prerequisite for strategic redirection or de-maturity. Indeed, the firm's previous experience indicates that an increase in knowledge and technology diversity helped the firm to initiate de-maturity from leather tannery to nonwovens and from consumer nonwovens to technical nonwovens. Thus, diversity is a critical factor for *evolutionary fitness* and *sustainable competitiveness*. This argument will be analysed in greater detail in the next section.

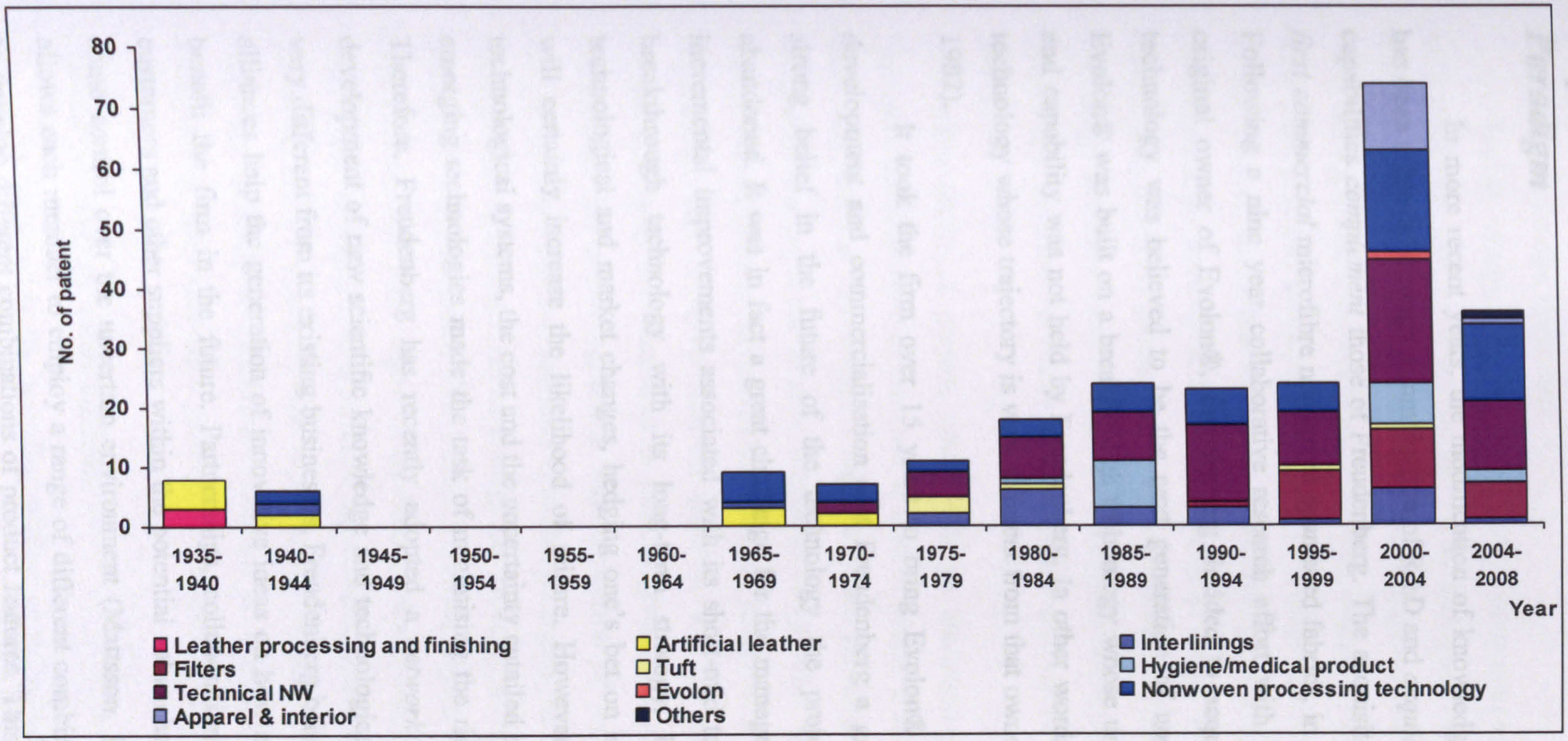

Figure 7-3. Patent portfolio for nonwovens according to publication date
Source: European Patent Office

Note: General patent group includes manufacturing methods and techniques that can be applied to a broad range of application. The period between 2004-2008 does not represent the final result.

Acquisition of External Knowledge – the Open Innovation Paradigm

In more recent years, the modification of knowledge and resource-base has been achieved through a combination of R&D and *acquisition of firms* whose capabilities *complement* those of Freudenberg. The acquisition of Evolon®, *the first commercial* microfibre nonwoven spunlaced fabrics, in 1999 is an example. Following a nine year collaborative research effort with Rhone Poulenc, the original owner of Evolon®, Freudenberg decided to acquire the firm as the technology was believed to be the next generation of nonwoven technology. Evolon® was built on a breakthrough technology whose underlying knowledge and capability was not held by Freudenberg. In other words, Evolon® involves technology whose trajectory is very different from that owned by the firm (Dosi, 1982).

It took the firm over 15 years to bring Evolon® to the market. The development and commercialisation cost Freudenberg a great deal. Without a strong belief in the future of the technology the project may have been abandoned. It was in fact a great challenge for the management to balance the incremental improvements associated with its short-mid term strategy and the breakthrough technology with its long-term strategy. In an era of rapid technological and market changes, hedging one's bet on a specific technology will certainly increase the likelihood of failure. However, the complexity of technological systems, the cost and the uncertainty entailed in the development of emerging technologies made the task of minimising the risks very challenging. Therefore, Freudenberg has recently adopted a *network of alliances,* in the development of new scientific knowledge and technological know-how that are very different from its existing businesses. Freudenberg believes that networks of alliances help the generation of innovative ideas on how new technologies can benefit the firm in the future. Partnerships, collaborations and alliances with customers and other suppliers within the potential value chain are crucial to gain some control over the uncertain environment (Mattsson, 1988). This approach allows each member to employ a range of different combinations of technology to develop different combinations of product features. This approach allows the firm to test the market and find the most promising markets prior to a commitment of major investment.

Indeed, as argued by Rosenberg (1996), there are two major uncertainties associated with new technologies, that is, technological feasibility and eventual applications. Emerging technologies often come about in a very basic form and its future applications are unknown. Rosenberg suggests that the exploration of a wide variety of alternative paths will help to manage the uncertainties. However, as the cost of R&D has increased exponentially, relying solely on internal development to develop different technological routes is very expensive and risky. Thus, the development of networks of alliances to allow access to various knowledge and know-how belongs to other firms without the obligation to own it (which has an effect on costs) is an attractive and viable route (Helfat, *et al.*, 2007).

The STELLA project, which will be discussed in the next section, illustrates this approach. In this case, a team of people from different disciplines work together as knowledge integrators and learning agents. Knowledge integration is a major part of new technology and product development processes of which difficulties inevitably arise. It involves a number of complex experiments and employs different problem solving techniques. Successful alliances obligate firm members to possess certain complementary assets and capabilities that allow interaction and transaction of knowledge from which unique, hard-to-imitate-capabilities could be generated (Helfat, *et al.*, 2007). The management of alliances has to manage the aspects that may generate conflicts from such a collaboration that include common objectives against individual firm's interests and the degree of freedom to access knowledge that belongs to other firms. In addition to contractual agreements, trust and reputation could be the safeguard of alliances. The capability to build and manage alliances is referred to as relational capabilities (Helfat *et al.*, 2007). Such an R&D strategy resembles the open innovation paradigm as discussed in Chapter 2.

Management of Innovation

As discussed in the preceding section, in the world of rapid market and technological change, management is confronted with the dilemma in the development of a technology strategy. The balance between technological development for the short and long term has to be achieved. Factors such as uncertainty, costs, internal competencies and the means to acquire new knowledge influence the process of decision making. The lack of capability to manage technological development was one of the fundamental weaknesses of Courtaulds (Coleman, 1980). In a highly diversified firm such as Freudenberg the complexity to manage innovation activities is great as each business needs different technological routes and pursues different markets with different characteristics and competitive environments. Therefore, the firm decided to introduce a decentralised structure in 1995 under which each firm operates autonomously to help to reduce the complexity and minimise inflexibility.

The firm has learned that R&D activities that are associated with existing businesses have to be separately managed from those that can potentially create new businesses. The separation is crucial as the existing businesses tend to neglect developments that are not directly related to their technologies and markets. Freudenberg manages its R&D activities into two different categories: 1) vertical research programme, that is, those undertaken within business units or firms. The R&D is aimed at the improvement and the defence of the competitiveness of the associated business units by means of continuous improvements; and 2) horizontal research programme refers to research projects that are not related to the existing business groups or involve a combination of capabilities across business groups or have an impact on several business groups. This is the long-term R&D programme and performed by Freudenberg Research Service[4] (FRS, formerly Central Research) with objectives to create new businesses and introduce radical innovations to the industry.

FRS manages five per cent of the annual R&D budget while the rest (95 per cent) is deployed for R&D programmes within the existing business units. Although the budget for the creation of new businesses is comparatively very small, the option to expand it remains open subject to the progress of each new

[4] FRS is responsible to undertake research projects that have no direct links with the existing business units, or that require synergies across-technological domains, including plasma coating technology and stretchable electronics. They are the research partner for all Freudenberg firms and subsidiaries in developing technology that have an impact across business units.

development. This demonstrates the firm's openness to change whilst maintaining its prudent approach.

As mentioned earlier, the management and commercialisation of new businesses away from the existing ones is the role of Freudenberg New Technologies (FNT) business group. Its mission is to reinforce and sustain Freudenberg's strength in innovation. It focuses on consolidating group-wide technical know-how, especially that of interdisciplinary technologies, to develop new products and technologies. FNT are responsible for three main tasks: creating internal new businesses (internal corporate venturing); acquiring promising technology developers whose products fit Freudenberg's interests through Freudenberg Venture Capital (external corporate venturing); and partnering with relevant business units in developing new products and process through the Freudenberg Research Service. Other tasks include obtaining public funds, technology scouting and screening, internal and external network support, promoting the development of the next generation of technology professionals and creating an open and innovation-friendly atmosphere. Other business units focus on the evolution of their core businesses through product improvements and expanding the share of different markets. Meanwhile the Management Board is responsible for providing the necessary guidance and advice for acquisitions. Freudenberg's innovation model is illustrated in Figure 7-4.

FNT is a critical business unit for the management of new competencies and the generation of capabilities through the mid-long term R&D programmes. As mentioned in Chapter 3, without a long-term technology strategy Courtaulds paid the price. The business unit also helps the firm to reduce the risk of the maturity-trap as it continuously seeks new pathways to pursue new areas of growth that are important to its future. As discussed earlier, networks of alliances are particularly crucial to this function. An FNT office in Brussels has been established to facilitate the development of networks within the EU.

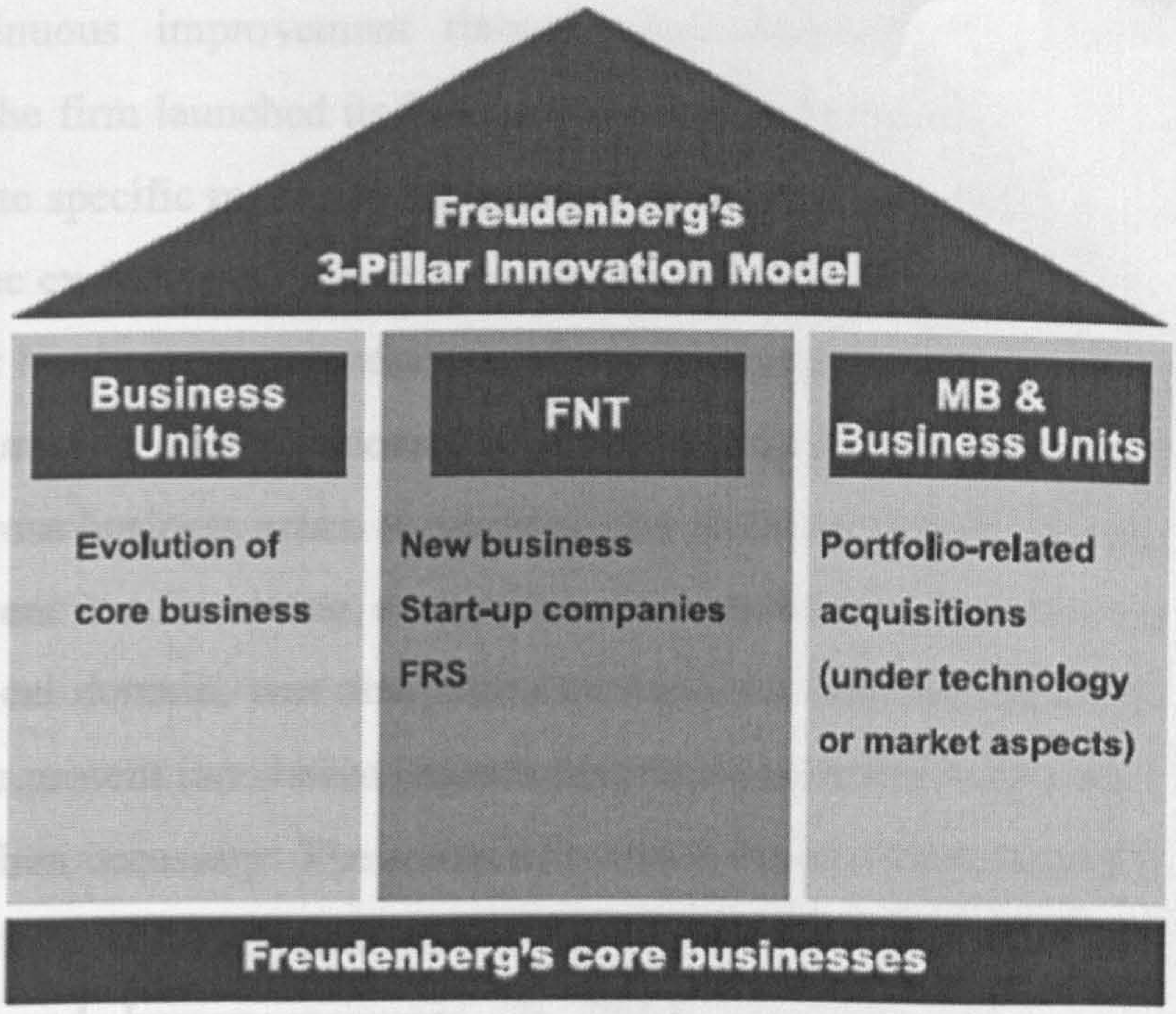

Figure 7-4. Freudenberg's 3-Pillar Innovation Model.
Source: Barth, T., & C. Wolf (2007, p. 4)

Separating the long-term developments from the short-term developments appears to be a sensible approach to ensure both programmes progress simultaneously. As discussed earlier, they have different characteristics that include the degree of uncertainty concerning technological feasibility and applications, costs and the appropriate approaches to obtain relevant new knowledge. Consequently, simultaneous programmes may be difficult to be implemented within individual business units. In fact, Christensen (1997) suggests that large firms are often too occupied with incremental innovations to satisfy their current customers (short-term development) to the extent that they overlook new external developments that may disrupt their technologies.

FNT can only benefit the firm when it can generate synergies between and among business units from which unique developments may be created. Communication channels between FNT and other business units have to be established. For that reason, the Management Board launched a number of innovation management programmes. The first programme was launched in 1992 through the GROWTH Programme (Get Rid of Waste through Team Harmony), a joint programme with its joint venture partner in sealing technology, Nippon Oil Seals Corp., (NOK) Japan. The programme attempted to implement the Japanese management system 'Kaizen' to achieve a lean manufacturing system and continuous improvement through cross-departmental teamwork. More recently, the firm launched its Innovation Offensive programme in 2003. Its aim is to initiate specific measures for innovation programmes, particularly those that concern the exchange of information (communication) and methods to achieve it. One result has been the introduction of the Innovation Forum (2003), a series of events created to facilitate communication and synergies among individuals or groups across business areas. In addition, the Global Innovation Forum (2008), a similar event but involving external experts to build a network in a specific technological domain, was also launched. It is a forum in which individuals or groups can present innovative projects and invite other business areas to join the projects when necessary. The scope of the Innovation Offensive programme has been continuously expanded since 2004 and now includes strategy, R&D indicators and human resources. In 2004, the programme introduced an innovation monitor, that is, a procedure to assess innovation projects and to estimate potential sales generated from innovation activities. In 2005, the R&D indicator – the number of patents, new products and process improvements- was introduced.

Following the introduction of innovation management procedures in 2005, the firm has conducted a thorough assessment and, subsequently, realigned its innovation strategy. The result indicated the need for *undivided attention from and participation of the senior management* in innovation programmes. Thus, the firm established the Freudenberg Innovation Committee (FIC) whose members are the Chief Technology Officers (CTO) of all business groups. They are responsible for the identification of *key markets* and *trends* in technologies of interest to Freudenberg and in fostering the development of new products. The FIC leads the assessment of the strategic direction the firm is likely to pursue in the future and provides judgments which technologies it should invest in. This is in fact the managerial capabilities argued by Helfat, *et al.* (2007) and Teece (2007) as one of the dynamic capabilities critical to enable the firm to identify future opportunities and threats and to take the necessary action. To reinforce such a strategic organisational capability the firm assigned a top executive to coordinate its new approach in the management of innovation in 2003.

Freudenberg believes that support from all employees is critical to the firm's success in innovation. Innovation should be integrated in the firm's culture and values (to be the leader in the relevant fields) and is shared across the organisation. The firm provides the necessary facilities and infrastructure to encourage individuals to leverage their knowledge and capabilities through training and development programmes; to communicate their innovative ideas across the entire organisation; and to join teams involved in new product development projects. Now, a large number of innovative ideas come from the employees and not from the top management.

Innovative ideas, however, will not benefit the firm if they are not translated into competitive products and successful in the market. The firm has developed routines to accelerate the progress from idea generation to commercialisation whilst managing the risks associated with new developments. The routines involve four milestones as demonstrated in Figure 7-5. The typical duration is three months to reach the end of the project stage with a €30,000 budget until end of the pilot stage.

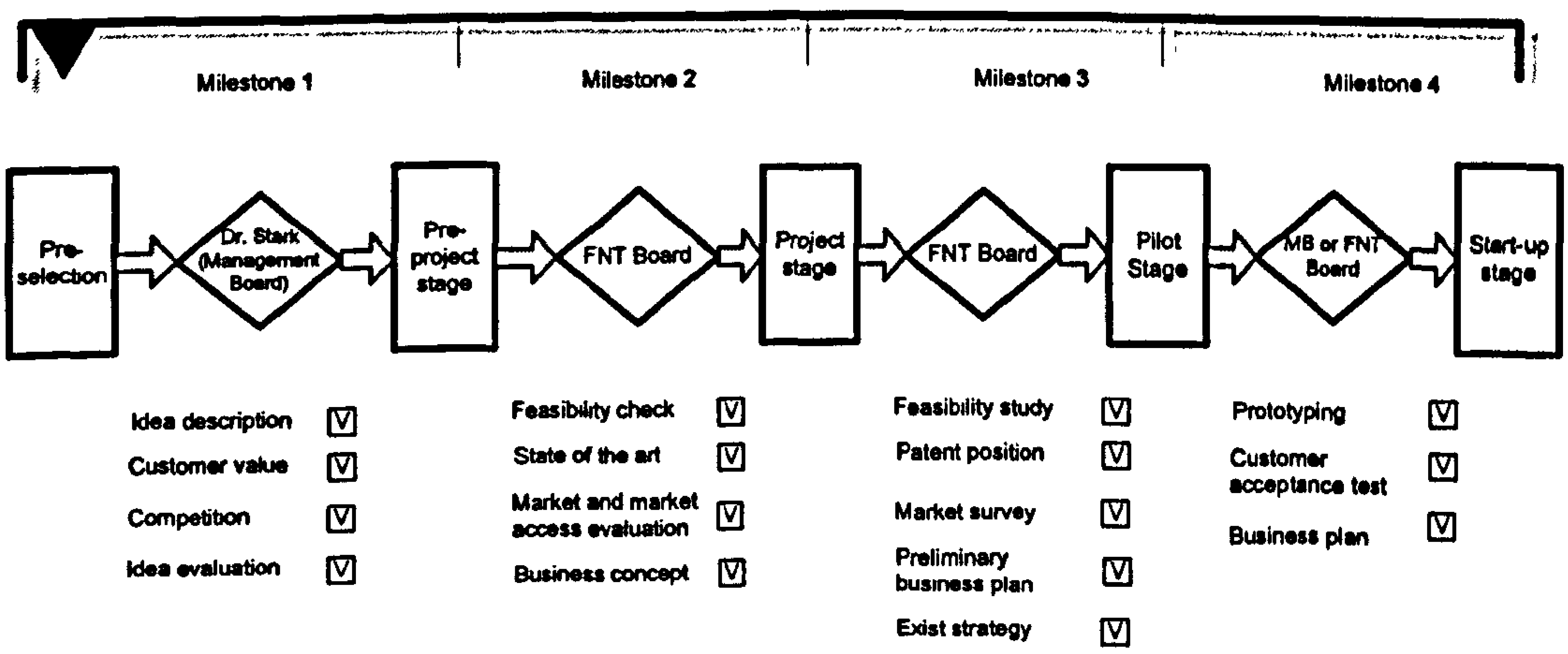

Figure 7-5. Stage-gate process in the Business Development Unit
Source: Wendelken and Wolf (2008, p.6)

To complement changes in business strategy and practices as a consequence of a shift in the R&D paradigm, the firm also changed its approach when it comes to commercialisation. Freudenberg can no longer restrict itself to beating a single path to the market. Chesbrough (2006) contends that failure in commercialisation among high technology firms was, in greater detail, more affected by market uncertainty than by technical uncertainty. He suggested that Xerox's failure to commercialise a number of its cutting edge technologies was caused by its traditional paths to market and by the need to serve its existing markets. It lacked a systematic process for exploring and evaluating alternative business models. In Freudenberg, this is the role of the FNT. The business unit develops the paths to markets –licensing, spin outs, sales, joint ventures- deemed to be suitable for individual product technologies.

It is evident from this case study that the capability to manage innovation is equally crucial as the capability to develop new technologies. While technology dynamics are crucial to the improvement of technical fitness, organisational dynamics are the underlying mechanisms to initiate, guide and progress changes and to improve the firm's evolutionary fitness. Together with the entrepreneurial capabilities of the management, they constitute dynamic capabilities described by Teece *et al.* (1997) as the determinants of long-term competitiveness.

7.2.2 The Evolution of Competencies

This section analyses the process of building (and termination) of new (and obsolete) competencies as the firm's response to the changes in technology and demand. It helps to explain the impact of the modification and the creation of new competencies on the ability of the firm to break away from its traditional roots and avoid falling into the maturity-trap.

The development of the knowledge-base that fosters the evolution of competence from leather tannery to nonwoven fuel cell components is exhibited in Figure 7-6. The study finds that technological change in the nonwoven business has been driven by the adoption of new materials (including polyamide, polyester and polypropylene) which is combined with different manufacturing methods from fibre extrusion to finishing processes. The firm possesses the entire set of technologies in nonwoven manufacturing (dry-laying, wet-laying, spunlacing, spunbonding and electrospinnng techniques). The possible end products derived from the combination of different materials and processing methods and finishing processes are vast. This enables the firm to have a diverse range of products to meet the requirements of an equal number of niche markets. The firm has the capability to customise different performance requirements for different groups of customers from the users of interlinings to diapers and from air and liquid filtration to wound compresses.

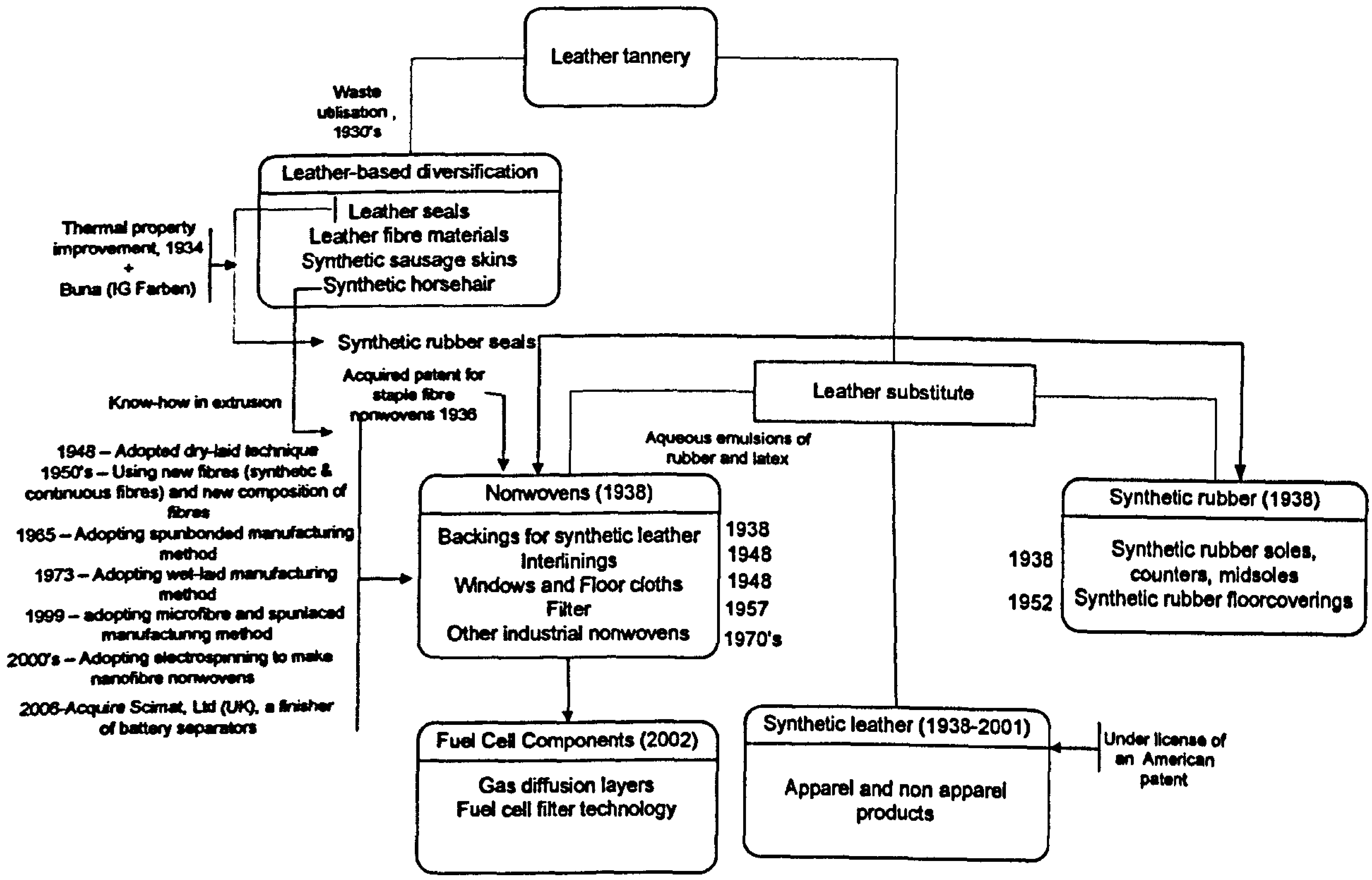

Figure 7-6. The transition of knowledge-base, product diversification and technology adoption
Source: the Author

Leather Products

Freudenberg's leather tannery business was the leader in Europe up to the 1920s when new competitors from developing countries managed to catch up with the German firm in quality. In 1927 the firm *hired* qualified chemists, Hans Siegert and Egon Elöd, to improve the quality of its patent leather so that its products could be sold to the high-end leather market segment. However, the Wall Street Crash in October 1929 followed by the Great Depression and World War II had a significant adverse impact on Freudenberg as well as Germany's leather industry in general. The firm suffered from a significant loss of export markets and from the disappearance of the leather raw materials market. The firm lost 75 per cent of its turnover and was left with a large inventory (1.5 million pieces of raw leather) of no monetary value.

The firm made attempts to generate a temporary source of revenue during the difficult period as its traditional markets had disappeared. It learned that there was an opportunity to substitute imported leather seals for the automotive industry as imports were blocked[5]. As the raw leather market had also disappeared, the newly hired chemists developed leather seals from the tannery' waste -a variety of shapes of leather scraps and pieces- in 1929. The automotive and machine-tools industries found Freudenberg's leather seals offered better performance and lower prices than the imported products.

The leather market reappeared after World War II. Freudenberg resumed its leather business and expanded domestically and internationally while the seal business flourished. The leather business reached at peak in the 1950s and 1960s during which Freudenberg was among the world's largest tanneries. From the 1970s onwards, however, the German leather industry reached maturity. It suffered from continuous decline mainly due to several structural problems which included: the emergence of new competitors particularly from South America; increased production costs; a changing market in which demand for leather upholstery took over the share of the leather apparel market; and plummeting demand following the oil price crisis in 1973. Under such conditions, Freudenberg was forced to downsize significantly its leather operation and close its international operations.

Despite the ominous losses, the management agreed not to abandon the leather business on the grounds that the business was part of the firm's historical legacy. To overcome the maturity problem, Freudenberg moved into *top-quality calf leathers* for more fashionable products. However, in more recent years, the luxury segment has been adversely affected by the global economic slowdown, particularly post September 11th 2001. The loss making leather business, which only contributed to 0.5 percent of sales in 2001, was terminated in 2002. Freudenberg's leather business had finally come to an end after 154 years.

In contrast, a temporary research project to developed leather seals from the tannery's waste turned out to be a decisive milestone in the firm's long-term growth. The seal business grew significantly and has replaced leather as the firm's core business since the 1970s. Freudenberg remains the leading supplier for the market it created 80 years ago. Its success rests on its ability to provide

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[5] In the introduction it was mentioned that the German government imposed on firms' conditions to reduce dependency on imports. This created new opportunities for the local manufacturers to supply substitute products.

competitive solutions to changing needs. The firm has continuously developed new products and processes as well as added functionalities to its seals. The automotive and engineering seal markets have stopped using leather materials. The firm adopted a range of synthetic materials to replace leather including synthetic rubber, silicone and metals which will be discussed in the following section[6]. One of its most recent innovations has been to incorporate sensors into the seals to enable the seals to monitor the rate of wear of the related components.

Synthetic Rubber

Access to new markets –the automotive and machine-tools manufacturing- through the development of leather seals facilitated a new learning ground for the firm. It learned that the market needed radial shaft seals which led to the development of 'Simmering', one of Freudenberg's most successful innovations, in 1932. However, the relatively low thermal stability of leather shortened its lifetime. Leather was therefore replaced with oil-resistant synthetic rubber (Buna) from IG Farben in 1934. This strategy is presumably related to government policy which imposed the adoption of synthetic materials on a wide range of industries. As a result of the adoption of synthetic rubber, the firm generated new know-how that was very different from its traditional one (leather processing). A new capability in the production of radial shaft made of synthetic rubber had been created.

In 1938, the firm established a crucial collaboration with IG Farben in the development of synthetic rubber 'Perbunan' to be used in a new type of seal made of high precision metal and synthetic rubber components. Following this, the firm had to adopt new production systems with higher technological complexity, and to have a better understanding of the science of synthetic rubber. The Main Laboratory and Central Workshop played a vital role in the development of the new technology. The application of synthetic rubber was expanded to include rubber soles (to replace leather soles) and floorcoverings. The firm continuously improved its knowledge in synthetic elastomeric materials

6 The products include simmerings, mechanical seals, membranes, high-precision moldings, bellows, dust caps, hydraulic accumulators, O-rings, hydraulic and pneumatic seals, cylinder head gaskets, frame gaskets, silicone seals, vibration control technology, special seals and brake components.

and developed new products with the new materials. Processing advanced elastomeric materials that include silicone and fluororubber is one of Freudenberg's key competencies used across its business areas.

Arguably, the firm has experienced a strategic redirection through the development of new competencies (the manufacture of leather and synthetic rubber seals) and access to new markets. The change was driven by adverse economic conditions which forced the firm to seek alternative sources of growth. This was facilitated by the emergence of new demand and was achieved through the adoption of new knowledge and know-how to harness new opportunities. As the complementary know-how was not internally available, the firm acquired new knowledge to the firm through the recruitment of new highly-trained scientific personnel and research collaboration with its supplier (IG Farben). Interestingly, the opportunity was seized on by combining their traditional competence in leather processing with new chemical processes brought in by the new partner. This shows the importance of cumulative nature of technological change in the strategic redirection (Rosenberg, 1994).

The new capabilities however can only benefit the firm when there is a market for its application. Therefore, technological innovation has to be complemented with an entrepreneurial organisation that can read emerging opportunities and to take the initiative ahead of its competitors. The utilisation of leather waste to develop leather packings to address the shortage of supplies prior to World War II shows the firm's entrepreneurial capability. The further development of this new capability, that is, the processing of synthetic rubber and other synthetic elastomers, and the links with the new markets (automotives, machinery manufacturing, construction) and their value networks (suppliers and customers) provided the firm with a new path for its future development. This shows the firm's innovative capability to look for and tap into *alternative sources of revenue* and to develop new capabilities accordingly. This development marked the firm's first attempt to initiate the process of de-maturity. These, indeed, are the characteristics of an organisation with dynamic capabilities (Teece, *et al.*, 1997).

Its entry in to the new market may -to some extent- be helped by the fact that competition was confined to local producers as the major competitors from the US had withdrawn from the market. This was in part because of the relatively low intensity of competition the firm managed to become a leading supplier of the seals market within ten years from the first adoption of the technology. The more important factor to its success was its innovative and entrepreneurial capabilities. Without those capabilities such an opportunity could not have been harnessed.

More importantly, those capabilities have enabled the firm to diversify into a new market, nonwoven fabrics, in which Freudenberg was the first to introduce the innovation to the market. As shown in Figure 7-6, its know-how in synthetic rubber (particularly in the aqueous emulsions of rubber and latex) helped the firm to develop a breakthrough technology, that is, nonwoven technology. Its pioneering technology has modified the knowledge-base of the firm and reconfigured its resource base (through new asset acquisitions and new recruits).

Nonwovens

Nonwoven[7] (or *Vliestoffe* in German) is a term created in the US in 1942 to classify a group of textiles produced by unconventional methods, that is, beyond knitting and weaving (Albrecth, *et al.*, 2006). Initially made of natural and cellulosic fibres, the arrival of synthetic fibres such as polyamide, polyester and thermoplastic polymers opened up new market opportunities and advanced the development of technology in this area. Various applications of nonwovens have been introduced and a number of processing technologies have been invented. Nonwoven technology has facilitated a market breakthrough through the creation of the *disposable market* whose applications ranges from tissues and diapers to wound dressings and tissue engineering. The major applications of nonwovens include; disposable diapers; filters; industrial cleaning; and disposable medical fabrics for surgical drapes, gowns, and sterilization wraps. The production of nonwovens is deemed to fit to the requirements for textile

[7] The definition of nonwoven adopted by ISO 9092 and CEN (EN 29092) is "a manufactured sheet, web or matt of directionally or randomly oriented fibres, bounded by friction, on/or cohesion, and/or adhesion, excluding paper and products which are woven, knitted or tufted, stitch-bonded incorporating binding yarns or filaments, or felted by wet-milling, whether or not additionally needled. The fibres may be of naturals or man-made origin. They may be staples or continuous filaments or be formed *in situ*". Manufacturing methods to produce nonwovens are dry-laying, wet-laying, spunbonding, meltblowing, SMS (a combination of spunbonding and meltblowing) and electrospinning. The critical objective of development in this sector, to which significant efforts have been and will be directed, is to supersede traditional textiles in apparel and household applications.

manufacturing in the developed countries as the most labour intensive part of textile production, weaving, knitting or sewing, is eliminated. Thus, the production of nonwovens is highly productive and cost-effective.

Freudenberg is now the largest and the most diverse nonwoven-producing firm in the world. It possesses 23 production facilities in 13 different countries, employs around 4700 people distributed in a large number of firms and generates annual revenues of €778.2 million in 2008. Its diversification into nonwovens appears to be a radical departure from its traditional leather tannery business. In reality, however, the firm experienced the change in a more evolutionary way. The new knowledge and know-how in nonwovens was originally acquired from a Dutch patent in 1936. The application of the knowledge was built on its established know-how in producing leather seals from leather offcuts and on its competence in processing rubber and latex. The know-how was used to lay fibres and bond them together to make layers of nonwoven sheet. The initial market they pursued was also the market they knew well, that is, the leather substitute market such as bags, school satchels, cartridge cases and the like and for military uses. Thus, during the development stage, the firm had the necessary information about the performance criteria to achieve. This approach to learn about the new technology was less risky as one of the dimensions of uncertainty (the market) was kept at a low level. This shows that a *radical departure* from the established businesses can be progressed through *evolutionary changes* of technology and market at the firm level.

The initial nonwoven technologies (and the outcomes) are very different from the current ones. The technology has experienced extended improvements, complemented with the arrival of various synthetic fibres (and filaments) and finishing techniques, which enables the firm to expand its practical applications. As shown in Figure 7-6 the firm has continuously adopted new processing technology which enabled it to highly diversify its products and markets. As the leader in the field, Freudenberg worked closely with the equipment suppliers and customers during the technology and product development processes.

To briefly illustrate, immediately after the Second World War during which the leather market reappeared, the firm shifted its nonwoven business from leather substitutes to interlinings and cleaning cloth (consumer nonwovens) using the dry-laid processing technique and natural fibres (mainly cotton). The arrival of synthetic fibres and filaments in the 1950s allowed the firm to develop products for technical uses. Filtration was the first diversification into technical nonwovens. The development in this sector was driven by its *vital joint venture* with two Japanese firms, Dainippon Ink & Chemicals Industry and Toyo Rayon Corporation (Toray) named Japan Vilene Company in 1960. The capabilities of those firms which were *complementary* to Freudenberg's technology fostered the development of various technical nonwovens. This is discussed in the next sub-section.

Technical Nonwovens

Interlinings had been the dominant revenue generator for Freudenberg nonwovens between the 1960s-1980s. The markets were not only for garments but also for shoes and backing materials for synthetic leathers. However, since the early 1980s the importance of consumer nonwovens has been superseded by technical nonwovens as the former approached maturity and the competitive advantage gravitated towards low cost producers. By 1991 the consumer nonwovens only contributed to 18 per cent of total turnover, while the technical nonwovens represented 26 per cent. Activities in this new sector began in 1957 when nonwoven for filtration was developed and by 1978 the firm had developed a range of products for various industrial applications including electrical insulation, battery separators (electrical), linings for floppy disks (computer), soundproofing materials and waterproofing materials (construction), tuftback (carpeting), air and liquid filter (filtration), plaster backings, wound compresses, diapers and ostomy bags (health and medical).

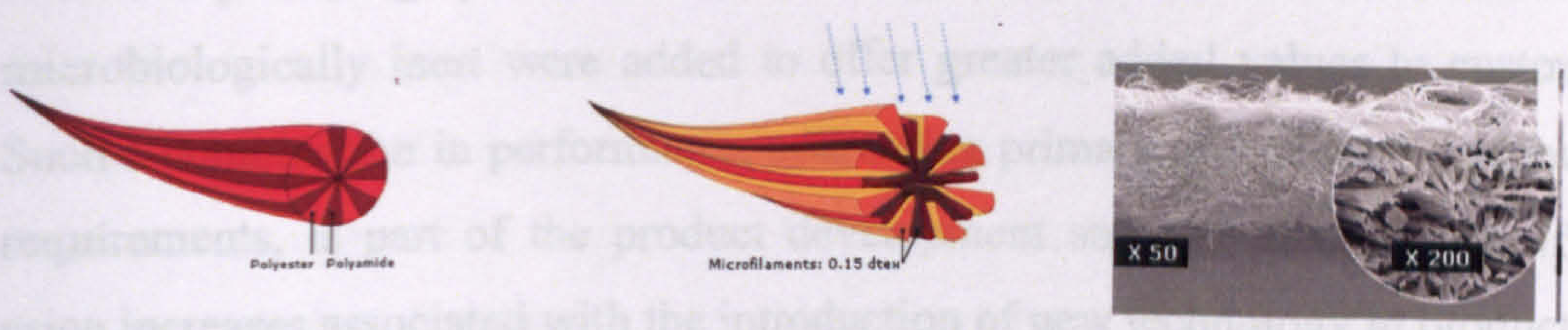
The capability to produce such a diverse range of products was a result of intensive R&D programmes, diverse knowledge and technology portfolio and being proactive in the creation of new markets. As discussed earlier, the firm continuously adopted new processing and finishing technologies and new materials to produce a wide range of products with desired performances. For instance, the adoption of the dry-laid method and polyamide fibres fostered the development of interlinings for various applications. The cost-efficient spunbonded polyamide nonwoven technology was developed internally in 1965 which enabled Freudenberg to enter the diapers market. This was then followed by the adoption of other new processing methods including: wet-laid polyester nonwovens; spunlaid nonwovens; lightweight spunbonded polypropylene for filtration and automotive carpet backings; water-jet-stabilised continuous microfiber spunlaces for apparel and cleaning industries; and electrospun nanofibre nonwovens for very fine filtration.

As mentioned earlier, the development and commercialisation of water-jet-stabilised continuous microfiber spunlaces (Evolon®) is an interesting case study. Rhone-Poulenc developed a process to convert polyester and polyamide chips into bi-polymer filaments in 1990. The bi-polymer filaments were split into microfilaments and subsequently tightly entangled and consolidated to make nonwoven fabrics. The method did not require binding agents or solvents, which was unique and significantly advantageous for cost savings and environmental benefits. More importantly, it eliminates the stiffness of nonwoven fabrics, a breakthrough development which increases the likelihood to compete with traditional fabrics. Following nine years of collaborative research with Rhone-Poulenc, the technology was acquired by Freudenberg in 1999.

The initial market for Evolon® was its established markets, that is, interlinings and automotive filters. Despite the unique production process, environmental benefits and vast potential applications Freudenberg's existing customers were slow to adopt the new products. This was due to the expensive production cost (it was produced in a semi commercial plant, hence, limited capacity and high costs), extensive R&D costs (over 15 years of R&D), uncertain technical problems and quality issues of the end product. The firm was faced by typical uncertainties related to the implementation of new technologies as described by Rosenberg (1996). Although Freudenberg frequently experienced uncertainties during the development and commercialisation of new technologies, the commercialisation of Evolon® was considered to be very problematic. The firm struggled to find a potentially lucrative application.

Freudenberg changed its strategy and established an autonomous firm to manage the development and commercialisation of the technology. The firm found that Evolon® could be a direct competitor to conventional textiles. The finding astonished the management as several attempts have been made to improve the existing nonwoven technologies to compete with traditional textile markets (clothing and household markets). In fact, competing with traditional fabrics had been the long-term strategic plan agreed among the nonwoven producers. The advantage of the new technology was that it reduced the stiffness of nonwoven fabrics significantly. This type of performance attribute is something that cannot be provided by the existing technologies. Moreover, the new technology offers higher strength to weight ratios, drapeability, has a soft-feel and is easy to clean. These properties are unattainable using other nonwoven technologies.

The market redirection was a great success. The technology competes favourably with woven and knitted fabrics as well as with staple fibre nonwovens. The application in the traditional textile market includes interlinings, workwear, footwear, and home furnishings, in addition to various industrial applications.



Polyester and Polyamide chips are spun into endless segmented filaments

The filaments are split into microfilaments with water jets

The water jets simultaneously entangle and consolidate the microfilaments, creating fabrics

Figure 7-7. Evolon®
Source: www.evolon.de

The most recent technology adopted by Freudenberg Nonwovens is the emerging biodegradable polymers and nanotechnology. Biodegradable polymers have been developed to address demand in tissue scaffolds. The firm has made several new developments to revive maturing markets including the development of carpet backings made from recycled PTE bottles (Lutradur Eco) in 2008. Meanwhile, Freudenberg envisages nanofibers as a complimentary technology to advance its nonwoven high-technology filter technology for dust removal, liquid filtration and membranes for bioreactors. The individual basic knowledge and technical know-how to produce filters made of synthetic nanofibres, that is, nanofibre forming and finishing technologies, and filter design and manufacturing, has been accumulated within the firm for a number of years. The capability to form nanofibres has been developed in recent years as an advancement of their established capability in bicomponent splitable microfiber and electrospinning methods that have been acquired since the end of 1980s.

An opportunity to develop high value added products derived from the combination those capabilities arrived with the recent *emergence of demand for cleanroom filtration* complemented with *higher industrial standards* introduced by the German government. The firm launched Viledon NanoPleat cassette filters for cleanroom filtration made of hybrid synthetic nanofibres (probably made of bicomponent fibres comprise of polyester and thermoplastic materials in the form of a sheath structure, core structure, an island structure or a side-by-side structure) at the end of 2007. The product sets new standards for indoor climate control technology, marrying fine filtration and large capacity to hold dust with energy-saving and longevity. Additional performance features such as being corrosion-proof, highly resistant to chemicals, 100 per cent moisture-resistant and microbiologically inert were added to offer greater added values to customers. Such a combination in performance, addressing primary and desired (secondary) requirements, is part of the product development strategy to offset significant price increases associated with the introduction of new technology in products for existing markets.

These new developments are still at the early stage of commercialisation. As with the early commercialisation stage of nonwovens and Evolon®, the future of these technologies remains uncertain. The current products may or may not be the eventual that are the most profitable. The technologies might not even find markets in the longer-term. In the case of the latter, the management has learned from the firm's experience that investment in knowledge and know-how is not a waste of resources. Reserved knowledge and know-how might find the application in or be a complementary for a completely different market in the future. With this belief, investment in R&D has been of strategic importance to the firm.

Adverse economic conditions do not hinder investment in R&D. The rise in the oil price in 2007 followed by the collapse of sales of the US automotive industry in 2008 caused a fall in sales by four per cent. This forced the firm to discontinue a number of production facilities to cut its losses caused by overcapacity. Instead of eliminating investment in R&D during the crisis, the firm vigorously sought out new emerging markets in which its vast knowledge and know-how in nonwovens could be applied. Its nonwoven fuel cell component technology (filters and gas diffusion layers) whose initial development was designed for the automotive industry was redirected to address the need for the stationary market in Japan (portable and household products) as the market in the country has been growing. To enter this market, Freudenberg teamed up with its Japanese partner firm, NOK.

The development of nonwoven business of Freudenberg shows its relentless efforts to develop new products and create new niche markets. An adverse economic environment does not hinder the firm from changing and innovating. In fact, the firm has managed to continuously find new growth in both in good and poor economic conditions. This shows its resilience to changing economic and business conditions. This can only be achieved through an unflinching commitment to continuous change. The fact that Freudenberg was the first firm to exploit a Dutch patent in Europe suggests that the firm possessed competitive capabilities in the commercialisation of the new technology. It is important to note that had the market for leather not disappeared in Germany, it is not clear whether Freudenberg would have adopted the technology. Thus, the adoption of the breakthrough technology appeared to be determined by the firm's assumption about the future market. This suggests that entrepreneurial capability is a fundamental factor in the selection of new competencies to be created.

Electronic Textiles

In addition to nonwovens, Freudenberg appears to have foreseen the potential applications of electronics in textiles and stretchable products for its long-term growth that include healthcare, functional clothes and integrated electronics. The firm's established knowledge in elastomeric materials was an entry point to join a network of suppliers and customers in the field. Engaging with such a network is crucial to have access to new knowledge that is far beyond its current competencies and to ensure the commercialisation of the resulting technology. The firm is currently acting as the consortium coordinator of STELLA (Stretchable Electronics for Large Area Application) project, a four year European research project (2006-2010) under the 6th Framework Programme. Partners in the project include Philips (NL), CEA (FR) and

Technische Universität Berlin (DE). One of the approaches uses textile compatible materials, thermoplastic polyurethane, to allow a complete system to be applied on various fabric materials. The electronic system can be laminated onto fabrics using thermopress. Several prototypes for specific applications have been developed, one being 'sensing' shoe inserts for patients with diabetes. Pressure sensors are being developed to give signals when the inserts need replacing. The system would assist in reducing the risk of feet inflammation and even amputation due to worn insoles. The electronics can be adapted for any shoe size and for each individual patient. For this application, Freudenberg sought a *partnership* with its former business group, Nora System, whose competence is in developing rubber floor coverings for a broad range of end uses, including nursing homes.

7.2.3 Drivers of Change

The case study reveals a number of critical factors that have empowered the firm to continuously change over an extensive period. Freudenberg's ability to continuously *search for new sources of income, its commitment to investment in R&D* and *its flexible approach* to *effectively* and *efficiently harness* new opportunities are the critical factors for change. The evolution of its competencies from leather tannery to seals to nonwovens shows that such a radical change progressed incrementally through the modification of an existing capability in leather processing. The incremental change resulted in new breakthrough technologies which were fundamental to the de-maturity of the firm. This shows a move away from mature businesses can be achieved through frequent modification of the established knowledge-base to serve different markets or technological speciation (Cattani, 2006). For the timeline of its technology and product trajectories please see Figure 7-8.

Frequent changes suggest that timing to adopt and commercialise new technologies is strategically crucial. Freudenberg appears to implement a first mover advantage strategy in the markets it has and will continue to enter. Figure 7-9 below shows the sequence of market entries by Freudenberg. In all these markets, Freudenberg was one of the pioneers in Germany (patent leather tannery, leather packings and seals) and globally (nonwovens). The figure demonstrates that the firm continuously creates new competencies and markets prior to the maturity of its existing technologies and markets. It suggests its ability to bypass the maturity-trap is through the continuous creation of new competencies that guarantees new growth.

The process of change was undertaken through the integration of externally-developed chemical processes into the existing competencies; internal R&D and collaboration with the suppliers and customers; and, more recently, through networks of alliances. The firm carefully selects the most appropriate innovation approach for individual R&D programmes. For instance, Freudenberg joined the EU funded R&D projects for its fuel cell components and STELLA projects. For the adoption of nanofibres into nonwovens, the firm opts to work internally or develops partnerships with German firms. Several factors determine its approach, primarily the availability of internal knowledge necessary to develop the technology, the cost of R&D, its R&D capability to develop particular products and the complexity to manage R&D projects involving various partners.

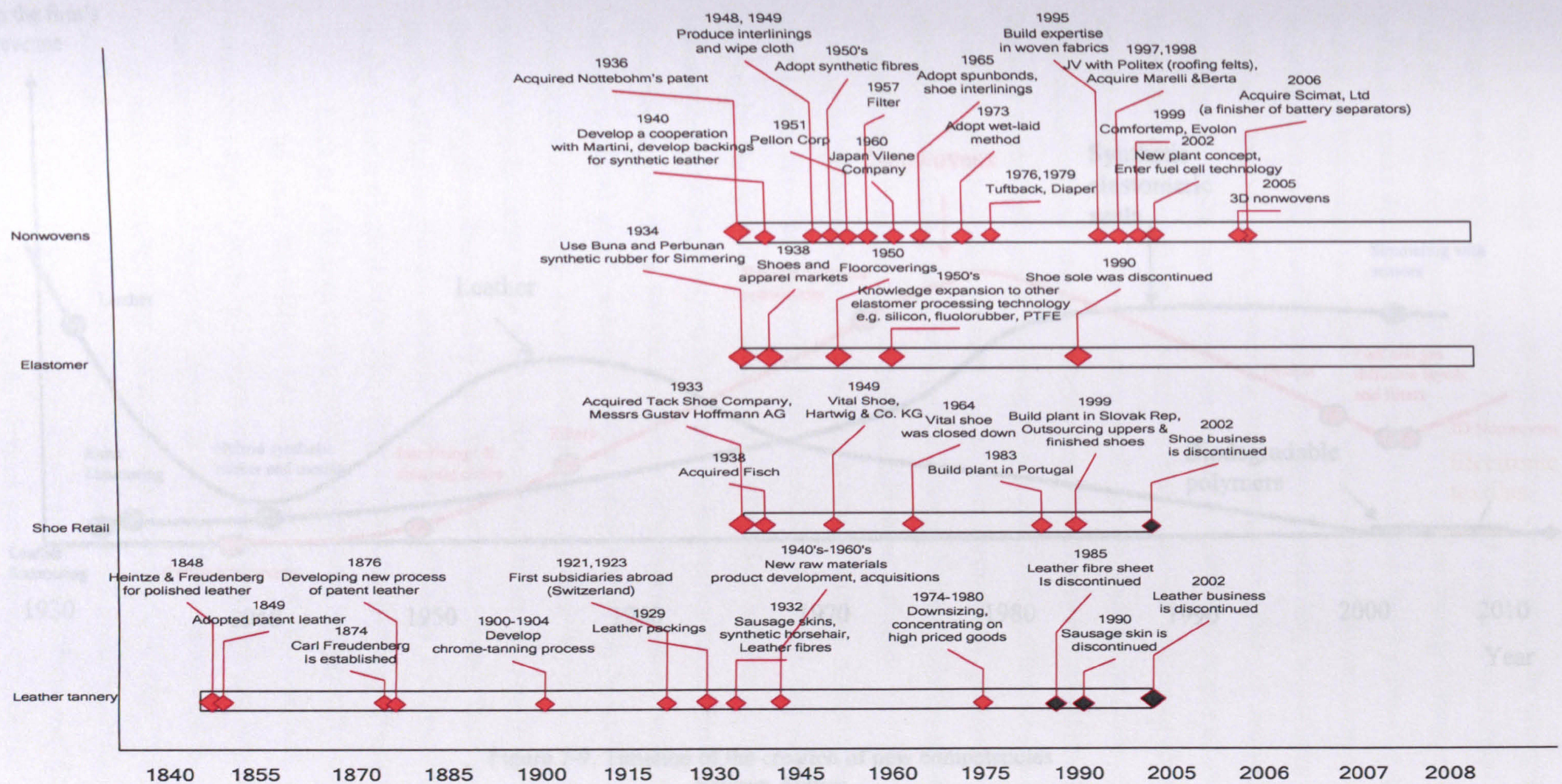


Figure 7-8. Technology and product trajectory timeline of Freudenberg
Source: the Author

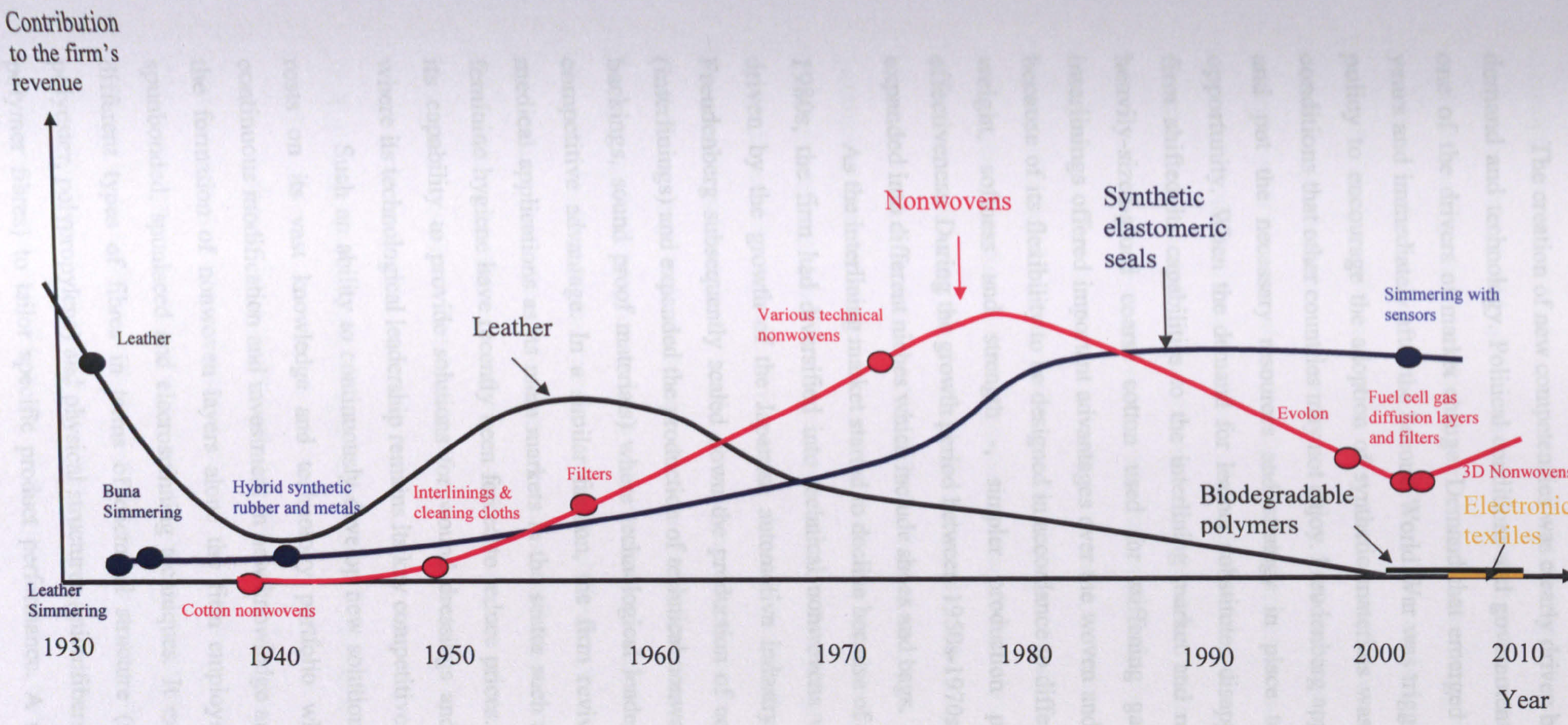


Figure 7-9. Timeline of the creation of new competencies
Source: Author

The creation of new competencies was clearly driven by changes in market demand and technology. Political conditions and government policies have been one of the drivers of market change. Demand that emerged during the interwar years and immediately after the Second World War was triggered by government policy to encourage the adoption of synthetic materials was Germany's unique conditions that other countries may not enjoy. Freudenberg appreciated the change and put the necessary resources and strategy in place to harness the new opportunity. When the demand for leather substitutes disappeared in 1948, the firm shifted its capabilities to the interlining market and replaced buckrams - heavily-sized-glued coarse cotton used for stiffening garments. Nonwoven interlinings offered important advantages over the woven and knitted interlinings because of its flexibility to be designed in accordance to different specifications – weight, softness and strength -, simpler production processes and cost effectiveness. During the growth period between 1950s-1970s the application was expanded into different niches which include shoes and bags.

As the interlining market started to decline because of cost pressures in the 1980s, the firm had diversified into technical nonwovens which were initially driven by the growth of the Japanese automotive industry in the late 1950s. Freudenberg subsequently scaled down the production of consumer nonwovens (interlinings) and expanded the production of technical nonwovens (filtration, tuft backings, sound proof materials) where technological leadership was its major competitive advantage. In a similar fashion, the firm revived its hygiene and medical applications as its main markets in the sector such as baby diapers and feminine hygiene have recently been forced to reduce prices. The firm leveraged its capability to provide solutions for wound dressings and tissue engineering where its technological leadership remains its key competitive advantage.

Such an ability to continuously develop new solutions for niche markets rests on its vast knowledge and technology portfolio which is a result of continuous modification and investment in new knowledge and technologies. For the formation of nonwoven layers alone the firm employs dry-laid, wet-laid, spunbonded, spunlaced and elecrospinning techniques. It exploits properties of different types of fibres in terms of chemical structure (such as polyamide, polyester, polypropylene) and physical structures (microfibers, nanofibres and bi-polymer fibres) to tailor specific product performance. A number of different bonding agents and finishing techniques (coating and different methods of plasma surface treatment) add up the diversity of the firm's technology portfolio. Such a *rich technology base* provides the firm with immense new opportunities for synergies and cospecialisation from which unique, sophisticated solutions can be created. The portfolio in other business areas is another source of knowledge and technology which can potentially be applied in nonwoven products. It works together with its materials and equipment suppliers to develop new products from the exploit them through different channels (business units, partnerships, joint ventures, spin out). This has fostered the application of nonwovens in, among others, automotive, construction, electronics, energy, medical and hygiene, computer.

Finally, the study indicates that being a family owned firm and yet managed by professional management and not by family members has a great advantage, particularly in the firm's flexible approach to long-term developments. The development of Evolon® which took over 15 years of R&D before the promising applications were found is a good case in point. Such a commitment to deploy resources to such a long-term development project may be more difficult to implement in a public firm. Those firms whose performance is constantly monitored and scrutinised by the shareholders to deliver results within a limited time frame may limit the likelihood to undertake long-term R&D programmes. Long-term R&D programmes can only be achieved with the *trust* and *support* of the shareholders in the management and sufficient *financial resources*. This shows that, parallel to the transition process which occurred in Ten Cate during the 1970s and 1980s, *continuity* and *consistency* were critical during the process of strategic change in Freudenberg.

7.2.4 The Dynamic Capabilities of Freudenberg

Undoubtedly, Freudenberg has the capability to initiate and manage change over a substantial period of time to sustain its competitiveness despite facing challenges from frequent changes in business and economic conditions. In addition to its tradition in technological innovation its competitive advantage is underpinned by its capability to radically change the organisation through the modification and reconfiguration of its resource base, and reorganisation. The modification and reconfiguration of the resource-base requires specific organisational capabilities to swiftly integrate new resources into the existing systems and to generate synergies among them. Reorganisation ensures the effective and efficient use of the modified resources. As these activities require investment the effect is permanent. Therefore, the ability of management to identify future paths to pursue where the likelihood of success is greater, the knowledge to acquire and the pathways to achieve it is vital. These are argued to be Freudenberg's dynamic capabilities that have enabled the firm to sustain its leadership in the global nonwoven market.

At Freudenberg, such an entrepreneurial approach is complemented with prudent implementation to minimise risk whilst maintaining long-term R&D of strategic importance. The firm has developed an assessment process in place to assess the potential risks and benefits (see Figure 7-5). Freudenberg believes that even in an economic crisis, removing long-term R&D programmes is counterproductive. It contends that firms which significantly reduce R&D activities in a crisis will face more difficulties when recovery takes hold than those which continue their R&D programmes. This is indeed a crucial element of the firm's dynamic capabilities

The firm's approach to seize new opportunities in leather packings and leather substitutes following the disappearance of its main raw materials is one of many examples of its creativity and entrepreneurial capability. Instead of scaling down its operation, the firm developed alternative materials to replace genuine leather. As the leading leather tannery in the country, Freudenberg had a market advantage over other firms in the field. However, the advantage could not benefit the firm without the ability of management to gather the necessary resources, accelerate the creation of new capability in nonwoven manufacturing and bring the new products on to markets in a timely fashion. The latter was critical as the window of opportunity for this market was narrow (around ten years) as the firm understood that the genuine leather would eventually reappear when the war ended. Thus, the firm needed to put in the necessary efforts to maximise the potential benefits within a limited time frame. Redirecting R&D in fuel cell component technology from addressing the needs of the automotive market to the stationary market as discussed earlier is another instance.

It is further argued that the dynamic capabilities are not only related to the creation of a new competence and capability. The new competence has to be extended, modified and refined to adapt to changes in market and technology. For instance, its competence in nonwovens has been extended to enable it to manufacture technical nonwovens. Within the technical nonwoven sector, the firm has modified and refined its competence to enable it to develop high value added, high performance products.

Freudenberg operates in a highly diversified market to reduce its dependency on a few market segments. This kind of organisation is less susceptible to changing economic condition. As explained earlier, the collapse of the US automotive market in 2008 affected the demand for Freudenberg's automotive carpet backings and filtration. Although the automotive industry was its largest customer, the collapse did not have a devastating impact on the firm as demand in other markets such as energy and medical increased.

Building synergies within its technology portfolio is evidently one of Freudenberg's critical dynamic capabilities. Such a capability does not only help the creation of idiosyncratic solutions as the resource configuration confined within firms is historically dependent and non-tradable as discussed in Chapter 2. Furthermore, it also plays a role in filtering and directing strategic investment. For instance, its decision to enter the gas diffusion layer and filtration markets for fuel cells was not only encouraged by the potential growth of the market but also by the potential synergies between its nonwoven capability and the competence of its partner, NOK. Freudenberg believes that the synergies can produce competitive technology which differentiates the firm from its competitors. Freudenberg does not pursue other related markets such as membranes, catalysts and electronics for fuel cells as the firm does not possess the sufficient know-how to make a significant impact on the market.

7.2.5 Implications of De-Maturity at the Firm Level

It is evident that Freudenberg has undergone a complete transformation, slowly morphing from a leather tannery into a highly diversified knowledge-based firm through a long process of transition in technology, product and market. The firm has undergone the process of de-maturity. The process of such a strategic redirection was started prior to the maturity stage of its traditional leather business, motivated by new opportunities beyond its traditional markets. The subsequent changes have been driven by changes in technology, market trends and government policy. The firm's established innovative culture has been the foundation of its ability to continuously change and adapt to changing external conditions. It excels in reading market trends, the adoption of new knowledge and the generation of new knowledge. Such a capability has fostered radical change in the firm's resource-base, business practice and organisational routines and structure. This is the capability which differentiates the firm from the majority of struggling firms in mature industries where more radical responses are often eschewed despite attempts to defend their mature businesses have failed (Abernathy, 1978, Sull, 2000).

Such a radical innovation provided the foundation for the firm to move away from its established competence when the related competitive advantage has diminished. The adoption of new technologies into its production systems has substantially modified the firm's resource base which included the stock of knowledge, skills, processes and machinery. This helped the firm to create new competencies to provide new competitive solutions for different markets beyond its traditional boundaries. When the leather business started to decline in the 1960s Freudenberg had already selected alternative paths for its future growth. Under such circumstances, Freudenberg could easily shift its resources to the new market because the uncertainty associated with the new technology and market (nonwovens) had been resolved. Thus, the firm has managed to *avoid the maturity-trap* through *broadening its technology-product-market portfolio* regularly earlier before its traditional business reached maturity. The finding suggests that performing (unrelated) diversified activities prior to the maturity of the core business can reduce the risk corresponding to resistance to change (inertia) in the mature industry or the maturity-trap.

Unrelated diversified activities do not necessarily mean conglomeration. On the contrary, Freudenberg has developed different activities in the fields where the firm possessed the underlying knowledge -related to market or technology or both- that could increase the likelihood of success. In other words, the development of knowledge is path-dependent as demonstrated in Figure 7-6 (Rosenberg, 1994). The current competencies were combined with the knowledge that was new to the firm to generate new knowledge to enable the creation of new solutions for new or existing problems. This implies that path-dependent change does not necessarily result in the phenomenon of lock-in as argued by Arthur (1989). In fact, it can generate new knowledge as long as the path of change is directed to generate new combinations of knowledge to provide solutions to new problems.

Freudenberg develops its knowledge-base through frequent improvements and modifications rather than radical changes through a series of acquisitions as observed in the Ten Cate case study. It initiated de-maturity through the enhancement of its established knowledge and the creation of new combinations so that it could be implemented in different markets. This was undertaken through the recruitment of new scientific personnel, R&D collaboration with the country's largest chemical firm, licensing, updating its processing technologies and joint ventures. Therefore, the firm experienced a less radical process of de-maturity than Ten Cate. Freudenberg's core business has remained the same over the past 70 years (seals and nonwovens) although the technology has changed entirely and the market is highly diversified. Other businesses have grown but the two main business areas still generate the firm's revenue today.

Nevertheless, the firm appears to have appreciated the importance of firm acquisition and network alliances as alternative pathways to add value to the firm's portfolio over the past few years. The acquisition of Evolon® and Scimat as well as the development of fuel cell filters and STELLA project are examples,. All acquisitions and alliances are undertaken to have access to knowledge and know-how that are not available internally that can strategically complement the firm's established competencies.

To ensure continuous renewal of its competencies the firm regularly updates its routines or creates the new ones to encourage innovation and commercialisation of new technologies. The routines, however, have to be complemented with the appropriate infrastructure and support from top management. The infrastructure is required to ensure the flow of communication across the entire organisation, while the support from the top management is necessary to ensure the availability of resources.

7.3 Conclusion

Freudenberg is an entrepreneurial firm. It has managed to survive two World Wars and the recent major global economic recession. The firm has developed dynamic capabilities to continuously change to adapt to changing business conditions, thus by passing the maturity-trap. These capabilities rest on the firm's high-level innovative capability developed through a long tradition in R&D, its unflinching commitment to long-term R&D and flexible approach to organisational structure and routines.

Changes in Freudenberg have been undertaken through frequent improvement and less-radical, path-dependent change in technology and organisational structure and routines. New ideas are initially progressed through small projects which involve low-level financial commitment to test the viability of the ideas before a greater commitment is required. In fact, changes and improvements are embedded in its routines to ensure continuity and participation of the entire organisation. Strategic change is not dependent on a specific figure but on accountable organisational processes and capabilities built up over a long period of time. The organisational process also ensures the balance between incremental and radical innovations can be achieved as they are managed in different units.

The routines that encourage change and innovation are improved and diversified overtime to adapt to new conditions. This is shown by the recent tendency to include acquisitions and networks of alliances in the mechanism to acquire and generate new knowledge. This new development was to provide access to diverse knowledge that was not available internally to anticipate the future development which was believed to involve complex technological systems, exponential increase of R&D costs and shorter technology life cycle.

The case study illustrates that continuous change does not necessarily reduce the diversity of knowledge-base or promote organisational simplicity as it has been widely assumed in the literature. Rather, frequent changes and technological speciation can lead to radical change in the knowledge-base and organisation or de-maturity. The key factor to avoid the maturity-trap or 'core rigidity' is to continuously modify the firm's resource-base through the adoption of new knowledge to provide new solutions to emerging markets.

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8

Conclusion

8.1 Introduction

This final chapter starts with a summary of why the European textile industry was selected as the subject for analysis, followed by a comparative analysis of the important findings. This is proceeded by a brief discussion on the implication of the findings to the EU programmes for the rejuvenation of the European textile industry. Areas where there is scope for further research is then suggested.

8.2 Summary

As noted in Chapter 1, the European textile industry was selected as a topic for research for three main reasons. Firstly, in contrast to the conventional wisdom which assumes that the textile industry is labour intensive and technologically stagnant, the European textile industry is highly dynamic. Its growth has been driven by the latest advances in science and technology. A fraction of the industry has changed its 'face' from a traditional to a knowledge-based industry. It is a result of a long process of 'reverse' transformation from the mature phase to the development phase or 'de-maturity'. However, the business and economic literature related to the textile industry has overly emphasised research on the process of transformation towards maturity rather than de-maturity. In fact, the literature appears to assume that the process of maturity is irreversible. It is one of the main arguments here to show that in contrast to the conventional assumption, the process of maturity can indeed be reversed. This gives new hope for textile firms operating in mature markets to experience renewed growth.

Secondly, Europe, which used to dominate the textile industry through Britain in the 19th century and through Italy and Germany from the 1970s, has experienced relative decline contraction over the past decade despite the protection of the MFA for 30 years. The industry found itself in difficult situation in the face of the emergence of new low-cost competitors, changing customers' preferences and shorter product life cycles. The industry appears to be heading for potentially serious danger if the necessary solutions can not be implemented in time.

Finally, the EU has shifted its approach to rescue the textile industry from protectionism to a more aggressive approach of intensive R&D and innovation programmes. The EU believes that the industry should be transformed from a traditional to a knowledge-based industry. Arguably, the programme can only benefit the industry if a large fraction of the textile firms can take advantage from the new inventions resulting from R&D projects. In other words, the diffusion of new technologies should be the central issue of the rejuvenation of the textile industry. However, the experience of the German textile industry shows that widespread diffusion of new technologies required at least two conditions. Firstly, government policy needs to provide incentives or other policy measures to encourage adoption; secondly, a certain level of innovative and organisational capabilities should be possessed by firms to adopt the new technologies to initiate the process of de-maturity. Otherwise, the likelihood of falling into the maturity-trap is very great. As the industry is predominantly (80 pre cent) populated by small firms with limited innovative and organisational capabilities, the attempt to transform the industry is going to be a major uphill struggle. Therefore, the firm level analysis to investigate the factors and processes by which traditional textile firms fall into the maturity-trap or successfully bypass the maturity-trap and initiate de-maturity is the most appropriate method to approach the problems. The findings of this thesis are thus highly relevant to support the development of EU policy in the rejuvenation of the EU textile industry.

8.3 Assessment of Findings

Attempts to rejuvenate the industry through the introduction of a new innovation policy and the European textile technology platform have started in 2004.

However the EU's response is argued to be too slow as the new policy was launched towards the end of the protectionist regime. This potentially limits the time available for textile firms to learn, adopt and commercialise the new technologies before other countries can catch up with the performance of the European textile firms. As discussed in Chapter 2, the section on the open innovation paradigm discussed how technology and product life cycle has been increasingly shortened as a consequence of intense competition and distributed knowledge[1]. As a consequence of this, the task to improve firms' innovative and organisational capabilities may be more challenging and costly.

What is quite alarming, inertia appears to have affected not only small textile firms but also large textile firms in Europe. Marzotto, one of the largest textile firms in Italy, believes that the firm does not need to initiate radical change. It contends that the crisis that has been affecting the textile industry is temporary. It believes that its old strategy, that is, production flexibility and multi-brand product portfolio, is sufficient to adapt to the current condition. Marzotto does not engage in any of the textile R&D programmes as it maintains that its prominent competence in design and flexible production of high-quality traditional fabrics is sufficient to satisfy its customers.

The strategy, however, may have a devastating impact for two reasons. It ignores the possibility that the change could be permanent as its customers may no longer be prepared to pay premium prices for luxury products given that a number of leading fashion houses have shifted their production to low-cost countries. Thia suggests that cost-based competition is no longer an exclusive characteristic of the low-end market segment. Although the firm remains optimistic and claims that it still enjoys growth, the global trend in the relevant market shows that the future may not be very bright. Secondly, the strategy lacks any 'unique quality' as it has been implemented by the majority of firms in the market for decades. As its competitors follow the same strategy and if brands, designs and quality could not improve sales, costs may be the only competitive factor. In the long term, cost competition may cause a devastating impact on the Italian textile industry.

[1] A condition in which knowledge can be accessed from a number of different sources. It is the opposite of concentrated knowledge where knowledge is monopolized by a few organisations.

Other textile firms who have successfully transformed their organisations to become high-tech textile firms respond to changes by increasing their R&D budgets and diversifying their activities to various sectors and market segments. The case study of Ten Cate and Freudenberg illustrates that changes in the business environment have encouraged the firms to look for new areas of growth through the adoption of new technologies and the commercialisation of new competitive products in various markets. They continuously expand the boundaries of the firm that include knowledge, know-how, assets and geographical location. Firms of this nature are not only responsive but, moreover, anticipate changes. In fact, change is embedded in their routines so that employees at all levels are involved in the process. This is one of their approaches to escape from the maturity-trap and be more adaptive to changing external conditions. This is one of their cornerstones of their long-term competitiveness.

It is important here to explain the fundamental differences between Marzotto, Ten Cate and Freudenberg. The summary of the findings can be found in Table 8-1. Using a comparative analysis, the following section examines the fundamental characters of firms falling into the maturity trap and those who have by passed the maturity-trap through continuous innovation and organisational adaptation.

Company and origin	Birth year and original business	Current business areas	Drivers for change	Dynamic capabilities	Main mechanism for change	Conclusion
Marzotto (IT)	1836 Wool fabric weaver	• Manufacture of woven woollen and cotton fabrics • Manufacture of linen and woollen yarns • Other business areas that are not related to textiles	• Fluctuation of demand • New fashion designs • Changes in process technology • Emergence of low-cost competitors	The capability to acquire firms and integrate them into the existing systems	Acquisitions, divestment and production relocation to lower-cost countries.	The firm is in danger to fall into the maturity-trap as the market and competencies are rather narrow (low-level of diversity)
Ten Cate (NL)	1766 Linen trader	• Manufacture of advanced textiles and composites for diverse performance applications • Manufacture of geosynthetics • Manufacture of artificial grass • Manufacture of industrial textiles • Manufacture of specialised plastic rollers for printers and copiers	• Changes in the existing and the emergence of new markets • Advancement in science and technology • Emergence of low-cost competitors • Opportunities for acquisitions	The capability to anticipate and initiate changes through the development of new, unique competencies which have an impact on the firm diverse capabilities, markets and technological assets	• Acquisitions, divestments and R&D. Those capabilities have been improved over time in accordance to the firm's development and new paths it is pursuing. • Radical change	• The firm has been able to by pass the maturity-trap and continuously change to adapt to changing business environments. • The firm is dynamic and its diversity improves it evolutionary fitness
Freudenberg (DE)	1849 Leather tannery	• Manufacture of various seals and vibration control technology • Manufacture of adiverse nonwovens • Manufacture of specialties chemical • Manufacture of technologies based on mechtronics	• Changes in the existing and the emergence of new markets • Advancement in science and technology • Emergence of low-cost competitors	The capability to anticipate and initiate changes through the development of new, unique competencies which have an impact on the firm diverse capabilities, markets and technological assets	• Established tradition in R&D and long-term collaboration with suppliers. • The importance of acquisitions has increased recently • Frequent incremental changes	• The firm has been able to by pass the maturity-trap and continuously change to adapt to changing business environments. • The firm is dynamic and its diversity improves it evolutionary fitness

Table 8-1. Summary of the three case studies

Victims of the Maturity-Trap

Chapter 3 analysed the factors that triggered the loss of competitiveness the Lancashire cotton industry. A combination of uncertainty, a low-level of investment, ineffective government policies, fragmented industrial structure, a lack of collective actions, short-termism and inability to accurately recognise trend and change have been cited. Above all, the underlying cause of the decline was the industry's distinct structure, values and practices that had been very successful over a long period of time and had reinforced each other to become deeply entrenched. When the environment changed, the managers who could not change the traditional structure, values and practices confined their responses to the areas they knew very well. Under such circumstances the firms fell into the maturity-trap or were locked-in to the existing structure, practices, technology and market. The analysis of the decline of a Lancashire's once iconic firm, Courtaulds, confirms that those factors caused organisational inertia and its decline. In short, the maturity-trap is a result of *structural, institutional and managerial (or entrepreneurial) failure.*

It appears, however, that the maturity-trap is no longer exclusively a British disease. The Italian textile industry, the leader in Europe, believes the cost-pressure and its relative decline in the past decade is temporary. As the Italian textile firms relocate their production to low-cost countries to improve their productivity, the industry experienced serious contraction. The industry continues to use the same strategy it has employed for the past few decades. This is because traditions have become a constraint to change, production skills have become entrenched and large infrastructure and well established routines have become rigid.

In the development of technical textiles Italy is behind other European countries. Although the technical textile sector enjoys significantly higher productivity than the luxury textile sector, Italy's main market segment, the industry has not put any significant effort into developing the market. Although the Italian textile industry is the largest textile industry in Europe in terms of size and value, its productivity is considerably lower-level than that that of Germany and the Netherlands which have successfully shifted their textile production to performance textiles.

As discussed in Chapter 4, the industry's relatively slow progress in the diversification into technical textiles may have been influenced by its initial strategic choice to concentrate on the fashion textile market. This choice may lead to the unintentional exclusion of other factors, that is, the diffusion of synthetic materials into the textile industry. Although appeared not to have a direct linkage to their strategic choice it may cause long-term detrimental effects if the competitive environment changes. The exclusion of synthetic materials from the country's textile industry's strategic long-term development appeared to have been affected by the slow development of organic chemistry in the country. Italy was relatively behind in organic chemistry compared to Germany, Britain and France, the other three major textile producing countries in Europe. The knowledge in the field developed relatively slow as the majority of the country's consumption of special plastics were imported. The diffusion of knowledge in synthetic materials to the textile industry was relatively slow compared to that in other European countries with strong research tradition in organic chemistry (Britain, Germany and France). As a result of this, the linkage between the textile industry and the chemical fibre producers was not strongly encouraged. This is a strong contrast to the linkage between the textile industry, fashion designers and textile equipment producers which has been established since the late 1940s. The evolution of the industry is therefore constrained within the areas where its 'stock of knowledge' was more competitive, that is, in design, quality and flexible production systems. This indeed highlights the concept of lock-in by Arthur (1989) and path-dependence in technological change by Rosenberg (1994). Lock-in suggests low level diversity in knowledge and market (or specialisation). The experience of the Lancashire cotton industry demonstrates that specialisation may increase the likelihood of firms falling into the maturity-trap.

Furthermore, the structure of the Italian industry which has been claimed as the industry's uniqueness on which its competitive advantage (flexible production systems) has been built may potentially hinder the diffusion of knowledge and know-how in advanced materials science and engineering. The case study of Ten Cate and Freudenberg indicates that the process of de-maturity requires a certain level of innovative and organisational capabilities which can not be built overnight. Given the industry is predominantly populated by small and family-owned firms, the shift may be difficult and require an extensive period of transition.

It is suggested in Chapter 5 that the Italian textile industry should learn from its own experience when it successfully displaced the French *couture* concept in the fashion market. With its lower-cost solutions the Italian fashion designers introduced the prêt-a-porter concept and emerged as a new major competitor in the fashion textile and clothing market. This shows that the high-end textile market is not immune from lower-cost competitors as assumed by the stakeholders of the Italian textile industry. The Italian textile industry should learn from its own history which has made it competitive or become a dominant power in the first place. It is indeed the only way to learn how to escape from the maturity-trap and to initiate de-maturity.

Multi-Faceted De-Maturity

The case study of Ten Cate and Freudenberg illustrates the process of de-maturity and continuous change in textile firms. Similar to Marzotto, Ten Cate and Freudenberg were originally traditional textile firms with a history of more than a century. In a striking contrast to Marzotto, these firms have accomplished a complete transformation. Their areas of business have changed entirely and diversified well away from the original ones. Those firms have managed to by pass the maturity-trap through a continuous extension of boundaries related to every aspect of their businesses. This is the foundation for their sustainable competitiveness.

The analysis between these firms shows the different approaches, processes and capabilities required to initiate de-maturity and to lay the foundation for continuous change. As with Marzotto, Ten Cate built up dynamic capabilities from its solid experience in firm acquisitions and divestments. Interestingly, although both firms use a similar mechanism, different objectives and implementation have different effects on those firms. Marzotto uses acquisitions for market expansion, (low level) diversification and vertical integration of production. On the other hand, Ten Cate uses acquisitions not only for market expansion and diversification but also for learning about new knowledge and developing new competencies. Acquisitions are also directed to build synergies among the capabilities of the individual firms to develop new idiosyncratic capabilities. For Ten Cate, acquisitions are used for the reinforcement of its existing capabilities as well as for the creation of the new ones whereas Marzotto appears to have used it to only reinforce its core capabilities. Consequently, whilst Ten Cate has by passed the maturity-trap, Marzotto is in serious danger of falling into the maturity-trap as it shows organisational inertia and 'core-rigidities'.

Freudenberg has shown a different path to by pass the maturity-trap and to manage continuous change. Freudenberg develops its knowledge-base through its solid tradition in R&D. This allows the firm to bypass the maturity-trap through continuous/frequent incremental changes and modifications to the resource-base than radical change as observed in Ten Cate case study. Technological speciation, that is, the modification of exiting capabilities to serve new markets away from its established market, has been identified as one of its primary approaches to de-maturity. Joint ventures are more preferable for Freudenberg than firm acquisitions.

Ten Cate initiated the process of de-maturity through acquisition of firms operating in different markets and employing different technologies. As a consequence of this strategy, Ten Cate has experienced a series of acquisitions, divestments, restructuring and changes in core businesses throughout its history. These may have caused organisational turmoil. Freudenberg, on the contrary, initiated de-maturity through R&D aimed at the enhancement of its established knowledge and the creation of new combinations so that it could be implemented in different markets. This was undertaken through the recruitment of new scientific personnel, R&D collaboration with the country's largest chemical firm and adoption of new technologies. Therefore, the firm experienced a less radical process of de-maturity. Freudenberg's core businesses remain in seals and nonwovens over the past 50 years although the technology it employs are very different from the original technology it used. The market has also changed beyond recognition. Other businesses have grown but the two main business areas still generate the majority of the firm's revenues up to the present day.

Ten Cate's model appears to facilitate faster results (radical change) than Freudenberg's model. To illustrate this, Ten Cate only required two years to master glass fibre processing technology for the protective clothing market (a completely new technology and market for the firm) since its participation in the ownership of Pierre Genin & Cie, a woven glass producer. In another instance, it took the firm only two years to establish itself as the major producer of windsurfing boards in

Europe. Freudenberg, on the other hand, required more than a decade to find the primary market for its nonwoven fabrics after securing a licensing agreement from a Dutch patent. However, the former arguably requires significantly larger investment and entails higher risks than the latter.

The different approaches in knowledge acquisition appear to be related to each firm's business strategy. For Freudenberg, as its strategy is to be the *first mover* in the markets it enters Freudenberg has to constantly generate new knowledge ahead of its competitors. It may not be able to find the necessary knowledge available for acquisition. Ten Cate, on the other hand, tends to be the *fast follower*. It permits the firm to acquire knowledge from external resources but it has to integrate the new knowledge and bring the product to market rapidly. In brief, Freudenberg is a 'knowledge generator' and Ten Cate is a 'knowledge integrator'.

The different approaches also appear to affect each firm's subsequent methods to generate new knowledge and develop new competencies. In contrast to Ten Cate which appears to be in favour for firm acquisition before R&D collaboration, Freudenberg prefers internal R&D, licensing, research collaboration, adoption of new processing technologies and joint ventures. The diversification was predominantly undertaken through a combination of purchasing new processing technologies, internal development, technology licensing, and research collaboration, particularly with the suppliers. Nevertheless, the firm appears to have increasingly appreciated the importance of firm acquisition and network alliances as alternative pathways to add value to the firm's portfolio in the past few years. Acquisitions target radical technologies which may revolutionise the industry and whose development trajectories are very different from the firm's technological expertise. The acquisition of Evolon® and Scimat are two examples.

These findings suggest that de-maturity can be achieved through a radical approach (Ten Cate's model) or a more incremental one (Freudenberg's model). Despite the differences, both models require prerequisites to foster de-maturity at the firm level. Firms have to possess a diverse strategic resource-base from which new alternative pathways for future growth can be built. Diversification of a resource-base can only be achieved through continuous learning and investment. Ten Cate has developed outstanding capabilities to manage the firm's business portfolio through acquisitions and divestment. The firm has the capability to search complementary resources external to the firm which add value to the firm's portfolio and to integrate them into the current structure. These capabilities have enabled the firm to overcome the complexity and adverse effects of acquisitions. For businesses that have lost their competitiveness, Ten Cate reorganises them to increase their market value before putting them back on the market. On the contrary, Freudenberg has established a solid tradition in R&D and mastered a wide range of science and technology. Its extensive technology-market portfolio not only in the nonwoven business but also in other business areas such as specialty chemicals and surface finishing technology provides the firm with a myriad of possible new combinations that can be exploited in the future.

Another prerequisite is the firm's awareness about emerging markets and technologies. It is crucial that firms can commercialise new products earlier than their competitors. Both Freudenberg and Ten Cate have changed their diversification strategy since entering the technical textile market. Whilst operating in one (mature) market, both firms did not put significant efforts into radical diversification until the market started to decline. In the new market, new competencies have been continuously developed prior to the maturity of their established market and technology.

A diversified resource-base and activities do not necessarily mean conglomeration[2]. During the early period of transition, Ten Cate, due to its method to acquire new knowledge, appeared to be becoming a conglomerate. However, as the firm streamlined its technological capabilities the further development of the firm was apparent towards the selected areas that were related to its basic knowledge. Freudenberg increases its diversity through a synergetic development process involving joint efforts with other business units or external organisations. It has developed different activities in the fields in which the firm possessed the underlying knowledge -related to market or technology or both- that could increase the likelihood of success.

[2] Conglomeration is often called multi-industry company. It comprises of two or more companies operating in two completely different businesses or industries.

Implications of De-Maturity on Path-Dependent and Path-Breaking Change

As discussed in Chapter 2 path-dependent change does not necessarily lead to the phenomenon of lock-in. Deliberate attempts to be different from their competitors through the creation of new competencies illustrate the process of new path creation. New paths can provide firms with new alternative trajectories to pursue in the future to bypass the maturity-trap.

The findings of this study provide a new insight in the creation of new paths. As discussed in Chapter 2, the related literature suggests the different impacts of incremental and radical change on the creation of new paths. A number of studies suggest that a more radical approach through firm acquisitions (Ten Cate's model) is necessary to break out from the established trajectories. The incremental approach through internal development (Freudenberg's model), on the other hand, is more constructive to reinforce the existing resource-base. This study instead reveals a rather different finding. It found that both approaches can be implemented to enable path-breaking change. Whilst the impact of acquisitions on a firm's radical transitions have been widely discussed, the process of incremental acquisitions that can lead to path-breaking change has rarely been discussed. This study, to some extent, agrees with Narula (2001) that Freudenberg was in the position to create new knowledge/know-how in the relevant fields (knowledge generator) as it may not be available in the market for acquisitions. In other words, in the pre-paradigmatic stage –borrowing Narula's term for the period prior to the emergence of a dominant design- the availability relevant knowledge/know-how was limited or not easily accessible so that the first mover has to develop new knowledge. Consequently, in-house R&D, rather than firm acquisition, in combination with collaboration with suppliers was the norm to establish a dominant design. When the relevant knowledge and know-how have been well understood and diffused into different applications, new knowledge and breakthrough technologies could emerge from different sources. Evolon® is an example of a new breakthrough technology developed elsewhere which can not be developed by Freudenberg itself as the necessary knowledge is not internally available. Given the rapid development of knowledge in the field and the importance of the technology to the firm's competitiveness in the future, acquisition, rather than internal development, was the most appropriate strategy.

Without a doubt, de-maturity is crucial for the rejuvenation of the European textile industry. It is, however, vital to underline the risk that entails. As discussed in Chapter 3, many large firms failed during the transition process. Among the primary causes were late responses to undertake new development, the extent of change was not sufficient to initiate de-maturity and inappropriate mindset of the management to compete in a different competitive environment. Courtaulds' failed attempts to commercialise synthetic fibres and carbon fibres are two useful examples. Instead of experiencing de-maturity, those firms were forced out of business or being acquired by their competitors.

Traditional textile firms which aspire to undertake the process of de-maturity can implement either method which suits their own circumstances (knowledge-base, competitive environment, financial resources, networks of customers and suppliers, current markets and future markets to pursue). The management, however, has to realise from early on that the process could take a number of years continuously and cumulatively. The necessary resources have to be in place for the entire period or there is a risk the process will fail.

The de-maturity process may lead to a change of management. As demonstrated in the case studies, de-maturity requires management and staff with different behaviour, attitudes and mindset. During the process of shakeout conflicts and major disruptions may arise. These may delay or, even more, halt the process of de-maturity. An unstable environment is very likely to negatively affect the performance of the firm which makes it vulnerable to takeovers.

8.4 Implications for EU Technology Policy

As discussed in Chapter 1, the EU has introduced a new policy to maintain its competitiveness in the textile industry. The policy encourages innovation and new quality standards to replace its old strategy of protectionism. The policy includes research and innovation; education, training and social issues; environmental issues and consumer protection; intellectual property rights; and cooperation with Mediterranean countries to allow the relocation of production and outward processing. Among those programmes, the research and innovation programme has achieved the most progress. The introduction of the European Technology Platform and the instruments to finance innovation in textiles and clothing in 2004 has been progressed to create 31 research projects which involved 400 organisations (private firms and research centres) and €160 million government research funding between 2007-2009.

The research and innovation programme emphasises intense collaboration and synergies between firms and research organisations to develop breakthrough technologies and to help the industry to reinforce its technological leadership. A number of first-stage products generated from the programme have been showcased to attract commercialisation projects with the private sector. Whilst crucial and beneficial for a fraction of the firms in the industry, the programme is insufficient to transform the industry. As discussed in earlier, firms have to have a certain level of 'absorptive capacities' to appreciate new technologies, and innovative capabilities to adopt and commercialise the new technologies. Without the improvement of these capabilities the diffusion of new knowledge will be confined within those with the necessary capabilities. This will exclude textile firms with low-level absorptive, innovative and organisational capabilities which can not appreciate the importance of and take advantage from the new technologies for their long-term growth. Unfortunately, the majority of the European textile firms fall into this category.

The emphasis on research collaboration and synergies is highly beneficial to foster the generation of new knowledge as discussed in Chapter 6 and 7. This, however, can only benefit firms which have the capabilities to be exchanged for the collaboration. Moreover, the commercialisation of the new knowledge will be highly related to the long-term relationship among the collaborators as each collaborator controls a portion of the intellectual property (IP) and complementary resources. If, for instance, the collaboration breaks down a number of issues related to IP and complementary resources may hinder commercialisation.

In brief, the EU programme for the rejuvenation of the textile industry may have a limited impact on the future competitiveness of the industry. A large number of firms cannot benefit from the programme as they do not have the necessary capabilities. Unfortunately, the capabilities can not be built overnight. The experience from Japan and Germany show that radical industrial transformation could only be achieved through *state-led concerted efforts* involving all the stakeholders (state, banks and industry) towards the acquisition of technology and the creation of industrial systems. In addition, entrepreneurial management and good leadership have to be in place to help traditional firms to break away from their outdated traditions, value and practices and to develop new competencies. Collective actions among stakeholders should be encouraged for the improvement of innovative and organisational capabilities.

8.5 Suggestions for Future Research

This thesis analyses the process by which firms in a mature industry can fall into the maturity trap and how they can successfully bypass the maturity trap through continuous innovation and organisational adaptation. There are, however, a number of related areas that are not covered by this thesis but are highly relevant. Areas for future research are those related to; the capability of small textile firms to improve their innovative capabilities; the sustainability of acquisitions as a means for strategic redirection in the face of a very competitive business environment and rapid technological change; the affect of being a publicly-listed firm on long-term technological development; the effectiveness of collaborative research and networks of alliances for the commercialisation of radical innovations; and the application of the de-maturity framework on other mature industries.